



VSMM 2008 – Digital Heritage – Proceedings of the 14<sup>th</sup> International Conference on Virtual Systems and Multimedia



# Digital Heritage

## Proceedings of the 14<sup>th</sup> International Conference on Virtual Systems and Multimedia

### Project Papers

This volume contains the Project Papers presented at VSMM 2008, the 14<sup>th</sup> International Conference on Virtual Systems and Multimedia which took place on the 20 to 25 October 2008 in Limassol, Cyprus. The conference title was "Digital Heritage: Our Hi-tech-STORY for the Future, Technologies to Document, Preserve, Communicate and Prevent the Destruction of our Fragile Cultural Heritage".

The conference was jointly organized by CIPA, the International ICOMOS Committee on Heritage Documentation and the Cyprus Institute. It also hosted the 38th CIPA Workshop dedicated on e-Documentation and Standardization in Cultural Heritage and the second Euro-Med Conference on IT in Cultural Heritage. Through the Cyprus Institute, VSMM 2008 received the support of the Government of Cyprus and the European Commission and it was held under the Patronage of H. E. the President of the Republic of Cyprus.



20–25 October 2008  
Limassol, Cyprus

M. Ioannides, A. Addison, A. Georgopoulos, L. Kalisperis (Editors)

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# VSMM 2008

## Digital Heritage Proceedings of the 14<sup>th</sup> International Conference on Virtual Systems and Multimedia

20–25 October 2008

LIMASSOL, CYPRUS

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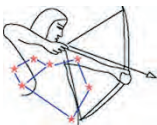
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# Foreword

These conference proceedings contain a selection of papers that focus on multi-disciplinary research involving both Cultural Heritage (CH) Informatics and also the use of technology for initial data-capture and digitization, information data-processing, reconstruction, modelling, visualization, documentation and archiving, as well as visualisation of results and dissemination to the scientific and cultural-heritage communities and to the public. The contributions in these proceedings will definitely assist all experts involved in Cultural Digital Heritage in restoring, renovating, protecting, documenting, archiving, and monitoring history and prehistory, to secure this information for years to come. It is clear that a worldwide collaboration in this area will help make the past accessible to the present and the future.

Cultural Heritage is being transformed by the nature of digital representation of culture in which production, documentation, and distribution of an artefact are one and the same. Understanding and defining digital cultural heritage has implications for documentation practices and the experience of cultural institutions.

Digital devices provide unique access to archives and cultural exhibits, enhancing the capacity of museums and collections to encourage community building and civic engagement. Collection databases once used solely by museum professionals are now being made available locally and globally through the Web. Increasingly, access to cultural heritage is digital and experienced through electronic images and facsimiles. Digital tools and information and communication technologies are merging as the basis for preserving cultural heritage. Digital 3D modeling provides precise and complete documentation of cultural heritage objects and sites and should be used in conjunction with traditional techniques. Of great interest to the scientific community in the last few years, especially in the areas of architecture and preservation, are 3-D modeling, visualization and animation of cultural-heritage monuments and sites. The cooperation between photogrammetry and computer graphics has led to the development of new tools and techniques that are particularly useful for the documentation and archiving of cultural heritage in a digital format. These new tools and techniques include not only photogrammetry, but also 3-D reconstruction, visualization, animation and virtual reality. Technical achievements in modeling, rendering, and animation have made possible the creation of virtual environments, providing a convincing visual experience of cultural heritage structures and sites.

The island of Cyprus is a particularly appropriate venue for a conference on Virtual Systems and Multimedia dedicated to CH because of the long and rich pre-history and history of the island. The historical and archaeological context of Cyprus is the physical and ideal setting of this conference. The past story of Cyprus is the history of the interaction of the cultures and peoples of the lands surrounding the Mediterranean Sea, which was the central means of communication, transport, trade and cultural exchange between diverse peoples. Its history is important to understanding the origin and development of the Mesopotamian, Egyptian, Persian, Phoenician, Jewish, Greek, Roman, Arab and Ottoman cultures and, hence, is important to understanding the development of Western civilization as we understand and experience it today.

The roots of cultures and civilizations are embodied in their architectural structures and archaeological sites, and this cultural heritage should be preserved for future generations. The importance of preservation can be seen in the efforts of international organizations to document important structures and sites. UNESCO and ICOMOS have called for all national and international organizations that are responsible for manmade monuments to document cultural-heritage objects and sites with methods that include traditional and newer, innovative technologies. The integration of these technologies offers great promise and the use of digital technology in particular has rapidly changed documentation techniques.

The importance of Digital Cultural Heritage is evident by the participation and cooperation of a large number of people and organizations including the following:

- The 14th International Conference on Virtual Systems and Multimedia VSMM 2008, dedicated on Digital Heritage (<http://www.vsmm.net/>)
- The 38th CIPA International Workshop dedicated on e-Documentation and Standardization in Cultural Heritage (<http://cipa.icomos.org>)
- The 2nd Euro-Med Conference on IT in Cultural Heritage.

We extend our thanks to all those, whose labour, financial support, and encouragement made this joint event possible. The International Program Committee, whose members represent a cross-section of Archaeology, Computer Graphics and Design, Architecture, Surveying, History and Engineering worked tenaciously and finished their work on time.



Especially Mr. Nikolas Valerkos, who designed and managed the webpage and Dr Andreas Lanitis who supervised the web-based submission system and guided the effort that published these proceedings. We would like also to express our gratitude to our co-organizers The Cyprus Institute, the Department of Antiquities in Cyprus and the Technological University of Cyprus. Finally, our institutional sponsors, the Ministry of Education and Culture, the University of Cyprus; and our official carrier, Cyprus Airways who provided money and 'gifts of kind' that made the conference possible.

Our Keynote Speakers, Javier Hernandez-Ros, European Commission, John Van Oudenaren, World Digital Library, *Library of Congress*, Massimo Negri, Europeana and European Museum Forum; Prof. Donna J. Cox, *University of Illinois at Urbana-Champaign*; Vassilios Tsingas, Elliniki Photogrammetriki Ltd; Kareem M. Darwish and Ahmed El-Shimi, *Cairo Microsoft Innovation Center*, are not only experts in their fields but also visionaries for the future of IT in CH. They promote the e-documentation of the past in such a way for its preservation for the generations to come.

Most of all we would like to thank the Cyprus Government, the European Commission, UNESCO WHC, ISPRS, ICOMOS, VSMM-Society and CIPA, that entrusted us with the task of organizing and undertaking this unique event and wish all participants an interesting and fruitful experience.

*Marinos, Alonzo, Andreas, Loukas  
Limassol, Cyprus 2008*

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# **Data Acquisition and Remote Sensing in Cultural Heritage I**



# THE IMPACT OF GPS TAGGING ON IMAGE BASED DOCUMENTATION AND 3D RECONSTRUCTION OF CULTURAL ASSETS

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**KEY WORDS:** GPS Tagging, Photo Communities, Imaged Based Documentation, 3D Object Reconstruction, Image Orientation

## ABSTRACT:

Since digital technology removed the darkrooms from photography not only photogrammetric methods migrated to new concepts. A wide range of so far not imaginable applications of electronic image processing became popular. The classic photogrammetric procedures, known as mono-plotting and stereo-plotting, running on desktop environments today, making use of epipolar line geometry, autocorrelation, feature extraction, automatic texture extraction e.g. In CAD environments one can find numerous texture mapping and photo matching functions. And finally computer vision breaks into the field.

Despite the hype of laser scanning, due to the accessibility of digital compact cameras and single lens reflex cameras in conjunction with GPS loggers, the photograph as a container of high information density plays an important role in the field of data capture and object reconstruction of cultural heritage objects. Range based methods require additional image information to provide photo realistic 3D models, whereas photographs contain range and radiometric information.

This paper discusses the possibilities of GPS tagging and GEO coding and figures out some applications with aspects of digital photography, photogrammetry and computer vision. Amongst others it instructs into GeoSetter, the KML 2.2 photo overlay tag, taking use of the ARC 3D web service and discusses on what terms pictures can be used in photogrammetry.

## 1. INTRODUCTION

Today people share pictures in photo communities. End of 2007 the Yahoo software Flickr hosted more than two billion images world wide. Adding global position information to the EXIF data of an image is known as GPS tagging. GEO coding is the process to extend image data with non-coordinate based geographical information. Those kind of meta data is important for searching and finding pictures in a global world-wide data base of images. Google released Panoramio, extended Google Maps with Streetview and upgraded the Google Earth Browser with functionality for displaying very large images and panoramas. Microsoft Photosynth takes a large collection of photos from an object, analyses and displays them in a reconstructed 3D space.

The above mentioned technologies therefore take effect to documentation and object reconstruction of cultural assets. It has to be considered that the methodologies named here, work like the wiki principle. People publish material world-wide for a large community. Googles 3D warehouse and the campus and city modelling contribution exemplify that principle.

From the point of view of cultural heritage documentation 3D object reconstruction is still being considered as a supplemental. High quality object reconstructions with respect to the structure of CAD systems are time consuming. There are surface models or solid models, both polygonal or curved based, known. Texture mapping reduces the effort in geometric modeling and yields to photo realistic looking models. Utilizing scanning technologies is leading in point clouds of high density. Mesh models, generated from those point clouds approximate an objects outer skin. Existing image information can be used for additional texture mapping.

This contribution was acquired as a preparation for a future project mainly build from photographs. GEO referencing seems to be the proper method, ordering the huge amount of photos. A major focus points to software tools available from the Web. 3D object reconstruction in terms of usability will be discussed.

## 2. GPS TAGGING

A digital still camera (DSC) stores embedded in the image data some kinds of metadata. Additional information is related to image data structure, recording offsets, characteristics and other tags. Among this metadata 31 tags are defined for GPS information.

The standard for storing interchange information in image files is EXIF (exchangeable image file format). EXIF is part of the design rule for camera file system (DCF), operated by the Japan Electronics and Information Technology Industry Association (JEITA [www.jeita.or.jp](http://www.jeita.or.jp)). The file recording format is based on existing formats. Compressed files are recorded as JPEG with application marker segments inserted. Uncompressed files are recorded in TIFF format. The specification is available from [www.exif.org](http://www.exif.org).

While GPS tagging deals with coordinate based geographical information, GEO coding extends image data about non-geographical based elements like postal addresses related to the coordinate data. A specification for storing text information related to image content is the IPTC (International Press and Telecommunications Council) standard. The standard enables interchanging of metadata between image agencies and



archives. Another format for storing metadata is the extensible metadata platform (XMP).

Linking GPS data to image data is performed simultaneously by clicking the camera shutter if applying the appropriate hardware or by software synchronising camera time with the recorded track.

Nikon digital SLR cameras are compatible to Garmin and Magellan GPS receivers via the serial interface. Mobile navigation devices mounted on the flash adapter can be directly connected to the camera. Red Hen ([www.redhensystems.com](http://www.redhensystems.com)) provides an adapter for Nikon cameras and off-the-shelf GPS units to directly capture geospatial referenced images. The GPS mounts on top of the camera putting it in full view of satellites and records latitude, longitude and altitude data to the EXIF header of each image. The physical integration provides hands-free use and the GPS data is displayed on the camera LCD.



Figure 1: GPS logger I-GotU, Sony GPS-CS1 and the Garmin etrex mobile navigation unit

Sony provides a small GPS logger for recording the position where photographs are taken. The GPS-CS1 is a small (9 cm / 3.5 in, weight 100 gram / 2 ounces) cylindrical device which the photographer carries with him while shooting pictures. It records the location and time. The supplied GPS image tracker software synchronizes the images with the latitude, longitude and time readings from the GPS-CS1 device.

A new GPS logger is I-gotU from Mobile Action, Taiwan. This device is only 47 x 29 x 12 millimetre small and weighs 21 gram. The storing capacity is 17.000 track points. Connection to the computer is realized via bluetooth or USB cable. The I-gotU GPS logger is targeted to the hobby photographer.

All units export data in multiple sharable file formats and are therefore compatible with mainstream software and web albums.

The Telepointer GTA ([www.gta-geo.de](http://www.gta-geo.de)) links the position together with the orientation, (direction of the exposure axis or viewing direction) directly to the image data. GTA uses that information in their software products supporting the process of texture mapping to buildings. So each photo carries the answer to the question "Where was it taken and in which direction is it looking?." GTA provides service for 3d modeling and is targeted to the professional market.

Figure 1 illustrates the GPS-logger I-GotU (50 \$US) and the GPS-CS1 (100 \$US) compared to a Garmin etrex Venture(200 \$US). Prices in parenthesis are roughly rounded. The differences in pricing can be taken as a performance indicator for the units. It has to be stated, that there is no barrier to act with a GPS mobile device during photo taking due to a high price or a bulky handling of a system.



Figure 2: Telepointer GTA mounted on a SLR camera (image source [www.gta-geo.de](http://www.gta-geo.de))

Mobile GPS navigation devices like Garmin or Magellan do not record only the position. It is possible marking waypoints, saving tracks and finding positions in the field. Maps, waypoints and routes can be loaded into the internal memory from external sources. Easy to handle communication software between device and external computer belongs to standard delivery.

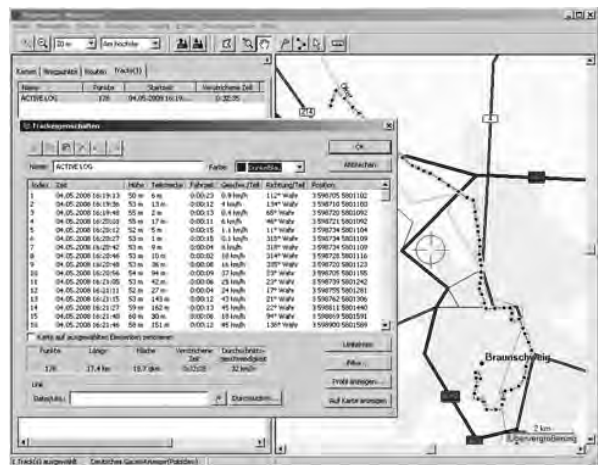


Figure 3: Garmin Trip & Waypoint Manager, import of the track log

Garmin comes with the Trip & Waypoint Manager software (see figure 3 for a screenshot) for reading out and storing data. A recorded track log contains time and GPS position. If a track is saved for tracing back, the timestamp will be lost for saving storage capacity. With this information in mind we focus to the

application of loading the track log information into the EXIF data of the images using a Garmin etrex with the Trip & Waypoint Manager and a freeware named GeoSetter. GeoSetter can be downloaded from [www.geosetter.de](http://www.geosetter.de). It is a multi-language freeware.

GPS tagging of images with GeoSetter starts with downloading the digital images from a camera into a subdirectory. In the same directory the GPS track log should be stored as a GPX format. GPX is a XML-based standard for GPS data. If one is interested in the complete GPS data set in NMEA format, use of software like visual GPS is recommended. Visual GPS is freeware and can be downloaded from [www.visualgps.net](http://www.visualgps.net).

Working with GeoSetter enables selection of images combined with a track log by synchronising camera time and GPS time. Connection between photo position and track is automatically interpolated and can be edited manually via the integrated Google map information. During updating the images the IPTC information is offered by standard information coming from the Google database. Output of a complete track can be saved in a KML file format and imported directly into Google Earth. GeoSetter does not write in the original image files, it stores a copy of the images including the updated information.

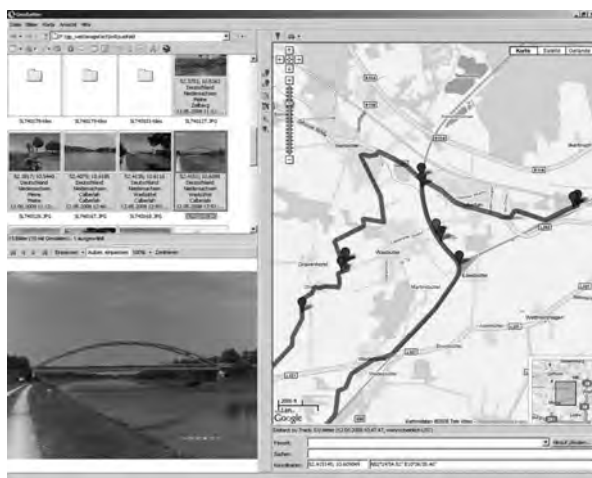


Figure 4: GeoSetter interface with images, track and image positions markers

### 3. IMAGE PUBLICATION AND DISTRIBUTION

#### 3.1 Photo Communities

Picasa is a software application for organizing and editing digital photos, originally created by Idealab now owned by Google. Picasa acts as a Web album, people can upload their photos into web space and share the albums with an authorized community. Picasa started as Shareware. Google began offering Picasa for free download since July, 2004.

Flickr is an image and video hosting website, web services suite, and online community platform. It was one of the earliest Web 2.0 applications, developed in Canada by Ludicorp, a company founded in 2002. Yahoo bought that company in 2005. Flickr is a popular Web site for users to share personal photographs. Bloggers use Flickr as a photo repository. Its popularity became Flickr by its organization tools, allowing

photos to be tagged and browsed by folksonomic means. As of November 2007, it hosts more than two billion images



Figure 5: Screenshot of Flickr

Panoramio is a geolocation-oriented photo sharing website. Currently, some of the photos uploaded to the site can be accessed as a layer in Google Earth, with new photos being added at the end of every month. The site's goal is to allow Google Earth users to learn more about a given area by viewing the photos that other users have taken at that place (source: [en.wikipedia.org](http://en.wikipedia.org)). Panoramio is reachable under [www.panoramio.com](http://www.panoramio.com).

#### 3.2 Google StreetView

Google Street View is a feature of Google Maps that provides 360° panoramic street-level views and allows users to view parts of selected cities and their surrounding metropolitan areas at ground level. It was launched on May 25, 2007. Google Street View displays photos that were previously taken by a camera mounted on an automobile, and can be navigated using either the arrow keys on the keyboard or by using the mouse to click on arrows displayed on the screen. Using these devices, the photos can be viewed in different sizes, from any direction, and from a variety of angles. (source: [en.wikipedia.org](http://en.wikipedia.org)).



Figure 6: Screenshot of Google StreetView

With Street View Google comes under criticism. People are afraid that there privacy protection may be hurt by the image recording (Smile! You're on Google's camera).

### 3.3 Google Photo Overlay

With Google Photo Overlay it is possible to publish very huge pictures or panoramas inside Google Earth. An image has to be prepared as an image pyramid with tiles of 256 px. The sample given here is a panorama of original size 8176 x 1126 px. The image is divided into 231 tiles numbered in a predefined order. The KML description reads as:

```
<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://earth.google.com/kml/2.2">
<Document>
<PhotoOverlay>
  <name>Ramingsmuehle</name>
  <description>Ramingsmuehle</description>
  <Camera>
    <longitude>7.5642</longitude>
    <latitude>52.5498</latitude>
    <altitude>34.0</altitude>
    <heading>0</heading>
    <tilt>90</tilt><roll>0</roll>
  </Camera>
  <Style>
    <IconStyle>
    <Icon>
      <href>http://www.imagefact.de/kml/
        ramingsmuehle-tiles/
        ramingsmuehle_$_[level]$_[x]$_[y].jpg
      </href></Icon></Style>
  <shape>cylinder</shape>
  <ViewVolume>
    <near>10.0</near>
    <leftFov>-180.0</leftFov>
    <rightFov>180.0</rightFov>
    <bottomFov>-23.396235</bottomFov>
    <topFov>23.396235</topFov></ViewVolume>
  <roll>0</roll>
  <ImagePyramid>
    <tileSize>256</tileSize>
    <maxWidth>8176</maxWidth>
    <maxHeight>1126</maxHeight>
    <gridOrigin>upperLeft</gridOrigin>
  </ImagePyramid>
  <Point>
    <coordinates>7.5642,52.5498</coordinates>
  </Point>
</PhotoOverlay></Document></kml>
```



Figure 7: PhotoOverlay details of a 8000 x 2000 panorama

The code snippet of the KML file demonstrates the photoOverlay tag. Including the tags for the shape, viewpoint (camera) and image pyramid information. It is obvious, that dividing the image into a pyramid of tiles requires a software-tool. I used the software PhotoOverlayCreator from the Centre for Advanced Spatial Analysis, UCL. Downloadable as a Java Archive from:

<http://www.casa.ucl.ac.uk/software/photooverlaycreator.aspna>  
The above given sample, displayed in figure 7, can be viewed from [www.imagefact.de/kml/raming/ramingsmuehle.kml](http://www.imagefact.de/kml/raming/ramingsmuehle.kml).

### 3.3 Microsoft PhotoSynth

Photosynth is a new technology to view photos on a computer platform. It was developed in a collaboration between Microsoft and the University of Washington.

A large collection of photos of a site or object is taken by Photosynth to analyses them for similarities, and displays them in a reconstructed 3-dimensional space. An object needs between 20 and 300 photos for 3D reconstruction. Pictures can be taken with different focal length lenses but must be presented in full format, since photosynth uses the EXIF data for further processing. After selecting the photos, no more interaction is required. The result will be uploaded automatically to the Web.

A user can navigate inside the scene by selecting the angle of view and the zoom factor. Information about the photo position in relation to one another is provided. With Photosynth fast access to gigabytes of photos is realized.

Photosynth needs installation of a plug-in for MSIE or Firefox and is running under Windows XP and higher. Access to Photosynth is given by <http://labs.live.com/photosynth>. Visit [www.photosynth.com](http://www.photosynth.com) for the latest release of the software. Figure 8 is a screenshot from a photosynth portal [www.nrw3d.wdr.de](http://www.nrw3d.wdr.de). The broadcast station WDR collects from its audience photos of selected monuments and brings them together as a synth. Approximately 100 photos are brought together for that reconstruction.



Figure 8: "Synth" of Hermannsdenkmal, a German monument

## 4. 3D OBJECT RECONSTRUCTION

3D object reconstruction is the most sophisticated container of documentation. It allows examination from any point the user selects, generation of video sequences and virtual walk through. Geometric modeling complies to the structure of the modeling tools. We distinguish surface models and solid models, polygon

based or curved based, and hierarchical polygon models. Sources of modeling are range based or image based recordings. Image based modeling speeds the time for recording on site and provides range and radiometric information. Surface models often provide only the textured skin of an object. The structure of buildings are represented by solid models. Automatic shape recordings result in point clouds and polygon models. In this chapter we focus on some principals and applications of image based methodologies photogrammetry and computer vision.

#### 4.1 CAD Photo Matching

Today one can find photo matching functionality in most CAD software packages. Photo matching is designed for two different tasks. First there is the problem to match a photo into a geometric model for texturing the environment or to visualize how a construction fits into its surrounding. The other task is to model 3D geometry from one photo.

For a successful photo matching, two pairs of parallel lines on perpendicular surfaces have to be set into the photos and an approximate scale is required. We follow here a sample worked out with SketchUp. In figure 9 one can detect the red lines for the x-direction and the green lines for the y-direction of the buildings local coordinate system. From the matched photo it is now possible to construct geometry in 3D space and to cut out automatically the textures needed.

One must consider, that in practice it isn't such easy as written in the manual. A result with good quality is automatically done only in particular cases. Most often a lot of time consuming fine tuning has to be carried out. Observe the shadow in the final rendering or detect other artefacts like the lantern in figure 10.

In SketchUp the photo matches are handled as scenes, defining camera position and orientation. Applying the GPS reference of the photo to those values enables global positioning of the model.

The kind of photo matching in Google SketchUp is known from the earlier Apollo Photo 3D software.

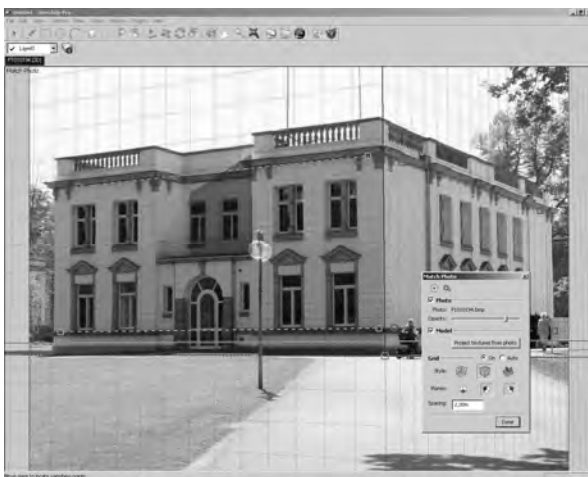


Figure 9: Photo matched by setting parallel line pairs onto perpendicular surfaces.



Figure 10: 3D model constructed from one photo with texture extraction

#### 4.2 Photogrammetry

Photogrammetry is defined as recording, measurement and interpretation of images or digital pictures with non-contact recording systems.

Applying photogrammetry minimizes the recording time on site and provides results with a high and reliable accuracy. Conditions for the adoption of photogrammetry are availability of a calibrated camera, the appropriate evaluation software and the operators profound knowledge.

The methodologies are grouped according to the numbers and arrangement of photos. There are single image measurements (mono-plotting), stereoscopic evaluations (stereo-plotting) and multi-image evaluations existing. Particular cases are the single image rectification and the orthophoto production.

**Single image rectification** takes advance from the projective relationship between an object surface and the image surface. With for control points on the object plane or two pairs of parallel lines, the transformation matrix can be determined to rectify an image.

A calibrated metric camera is not required. The rectified image is still a perspective, but the impact of camera rotations is eliminated. Image rectification is a common method in architectural applications. By knowing the ground dimensions from digital maps, elevation data can be easily derived from photographs.

Figure 11 displays the result of a workflow targeted to 3D modeling and use of non professional equipment, described in detail on the web under [www.imagefact.de/rectify](http://www.imagefact.de/rectify).



Figure 11: 3D modeling from rectified photos and digital maps

It is not possible, to get exact geometrical information from one image. If only one image is available, additional object information is required. Mono-plotting is the process, to intersect measurements in metric photos with object shapes. The **orthophoto**, rectified to a digital terrain surface model stands as a sample for such a method.

Two photos, taken with parallel exposure axis from a bar contribute to a stereo model. The stereo model can be viewed and evaluated by special equipment in 3D.

The first step in **stereo-plotting** is the interior orientation and image refinement. In case of images taken with digital cameras, the interior orientation (measurement of fiducial marks) is not necessary. But the image should be refined about the correction of camera parameters, the principle point position and lens distortion correction. The values are coming from the calibration certificate.

As a second step, reconstruction of the relative positions of both images to each other is required. This relative orientation can be done today automatically, by filtering interest points, as applied in the Z-GLIF Software from Menci. The result is a stereoscopic model.

Next a true scale and local coordinate system must be referenced for the absolute orientation of the model. Most common are control points in the object or a minimum definition of a local orientation and an object distance to evaluate in true scale.

After that two step orientation process, the evaluation of details applying point, line and polyline measurements in a CAD like environment can be accomplished. The parallax or disparity measurements can be taken in the stereoscopic model (anaglyph filtering) by setting a floating mark onto the model surface or in monoscopic mode placing the crosshair to the same point in both images. Automatic procedures are known as on-eye stereo.

Figure 12 is a screenshot from the Z-GLIF software, displaying the mono mode with two crosshairs and a depth map. Raw measurements should be overworked to the final CAD model and positioned into a global coordinate system as stated below.



Figure 12: Z-GLIF stereoscopic evaluation Software

The most flexible method in recording complex objects is the **multi-image** arrangement, working after a triangulation principle. The orientation is an iterative triangulation process. It starts from a left and right image. Comparing corresponding points yields to the model. From now on a change between resection and intersection in space let grow the field of orientation points and camera stations. A final bundle adjustment combines photogrammetric measurements with additional observations in the object space and reports about accuracy and reliability of the image bundle. The measurement protocol of detailed vector information has to be refined with CAD software as well. A common used software system of this type is Photomodeler from EOS Systems Canada.

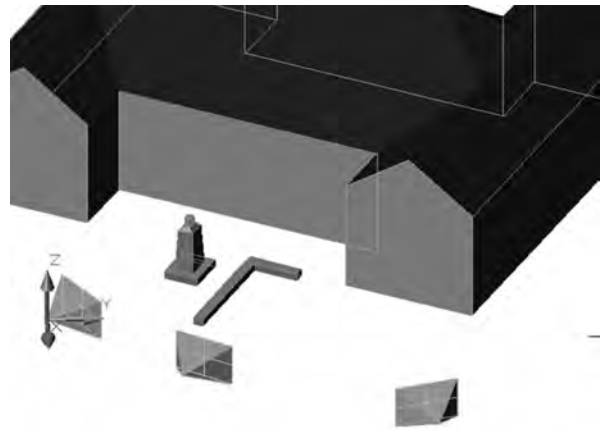


Figure 13: Exposure arrangement for multi-image photogrammetry with minimum of 3 photo positions

Image modeler from Real Viz follows the philosophy to generate a complete complex model structure from basic shapes inside the photo evaluation software. Modeling takes place directly in the photos up to mesh editing functions. Direct texture extraction is a pro for this workflow. Autodesk has overtaken (amongst others) the company Real Viz in mid of 2008. That indicates the importance of 3D modeling by photographs and the possible growing demand on that kind of software tools.

### 4.3 Computer Vision

Use of calibrated cameras and manual operating seems to be a disadvantage of photogrammetry. Computer vision methods target to the use of non calibrated cameras and totally automatic model reconstruction approximating the object geometry by triangular surface meshes, textured with image data. A solution resulting in a disparity map, confidence map, triangular surface meshes and the texture mapped scene by stereo image pairs was introduced by Koch. (Reinhard Koch, 1994).

Part of the agenda of EPOCH (network of European cultural institutions) is the development of cost-effective 3D acquisition technologies. The ARC3D web service ([www.arc3d.be](http://www.arc3d.be)) offers the possibility to upload an image sequence, utilizing the ARC 3D image uploader, to a server and analyse the 3D reconstruction downloaded from the server with the ARC3D model viewer (Vergauwen, Van Gool 2006).

After processing on the web network, the client downloads the findings as a compressed archive. The archive contains a file including the reconstruction information, for each image a thumbnail and the image texture, the camera data as a manifest file, the dense depth maps and the quality maps. The model viewer reconstructs on the client computer the 3D information. It is possible to mask the images, eliminating sky e.g., before reconstructing the surface meshes and surface texture. Final results can be stored in several formats.



Figure 14: MeshLab output, textured model and meshes including camera positions

In a second step the model can be refined with the MeshLab software tool, provided by the Visual Computing Lab, Italy, [vcg.isti.cnr.it](http://vcg.isti.cnr.it). MeshLab is a mesh processing system for editing and rendering unstructured 3D triangular meshes. Since the ARC3D web service does not require any coordinate information, the geometric model is not referenced to a higher order system. Figure 14 displays the textured model of a portal on the left. Shown on the right are the 3D meshes including the camera positions. Positioning the origin of the object system into a camera position enables the global positioning via GPS tagging as explained in the following chapter.

## 5. OBJECT ORIENTATION

Photogrammetric processing can be performed in model coordinates or local object coordinate systems. Image orientation is known as relative and absolute orientation. While measuring buildings, a local system fixing (parallel to one façade) is common. Such a definition uses the seven degrees of freedom of a coordinate system. Three translations, three rotations and one scale. Additional measurements at the object (control point information, distance measurements) applied to a bundle adjustment improve the reliability. In most cases a model refinement is required. From raw measurements a consistent CAD surface model or solid model has to be constructed. Compilation of the raw measurements into a CAD format must be performed. Converting the camera stations as well enables for absolute orientation of the model. Transformation of the origin of the local coordinate system into a photo position facilitates the orientation.

As introduced in chapter 2, the camera stations are GPS tagged. Calculation of the azimuth between two stations of proper distance provides complete orientation of the model, translation and rotation. One point of the base line is identical with the models local origin. The azimuth confirms by complete model rotation. Converting the model to KML results in a placemark, referencing the geometry to the Collada format. We only have to alter the latitude and longitude in the KMZ archive. A 3D photogrammetric model is now positioned with satellite accuracy.

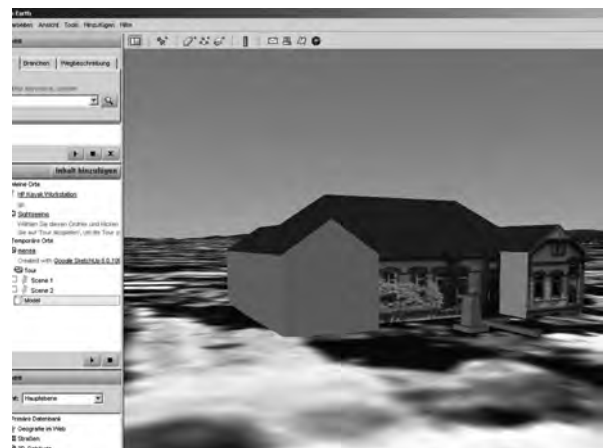


Figure 15: The textured model compiled to Google Earth

## 6. CONCLUSION

A photo is a container of high information density. Apart from drawings, text reports, measurements taken with scales, total stations or laser scanner the photo is a major tool for documentation of cultural assets. A photo hosts geometric and radiometric information. Utilising GPS tagging adds time and position of picture taking to the image data. Furthermore GEO coding refers to non-coordinate based geographical identifiers.

Those metadata can help searching after a variety of location-specific information. GPS tagging and GEO coding is the basic condition that people can share their photos in Web communities. The Web albums Picasa, Flickr and Panoramio have been introduced.

Google Street View, Google Photo Overlay and Microsoft Photosynth stay for new methodologies how photos can be presented via the Web in a 3D manner. Research goes in the direction of navigating in gigapixel images.

3D object reconstruction from photos starts from photo matching in CAD system, is performed by photogrammetric methods up to the fully automated computer vision systems. The quality of a model must be seen with respect to a users requirement.

Including the camera stations into the reconstruction enables world-wide global positioning of a 3D model generated from photographs.

According to computer graphics rendering procedures the following statement is cited:

*If you like it photo real, go out and take a picture.*

Today we can extend:

*... and don't forget your GPS logger.*

**Remark:** All the small examples presented in the text are used as a feasibility study for administrating a future large project. Selection of the objects is accidentally. Usefulness depends on the particular requirements.

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# THE IMPORTANCE OF CONSIDERING ATMOSPHERIC CORRECTION IN THE PRE-PROCESSING OF SATELLITE REMOTE SENSING DATA INTENDED FOR THE MANAGEMENT AND DETECTION OF CULTURAL SITES: A CASE STUDY OF THE CYPRUS AREA

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**KEY WORDS:** Remote sensing measurements, atmospheric correction, cultural heritage sites, pre-processing

## ABSTRACT:

Solar radiation reflected by the Earth's surface to satellite sensors is modified by its interaction with the atmosphere. The objective of atmospheric correction is to determine true surface reflectance values by removing atmospheric effects from satellite images. Atmospheric correction is arguably the most important part of the pre-processing of satellite remotely sensed data and any omission produces erroneous results. The effects of the atmosphere are more severe for where dark targets are shown in the satellite image. In the management of cultural heritage sites, since temporal satellite images are required for monitoring purposes, the effect of the atmosphere must be considered. Classification techniques are also required to map land-cover changes in the vicinity of important cultural-heritage sites. Detection of important cultural heritage sites needs effective post-processing techniques. Indeed, any unsuccessful attempt to remove the atmospheric effects from the satellite remotely sensed images may cause non-reliable reflectance values. The paper presents a method of assessing the need for atmospheric correction, and addresses the importance of removing atmospheric effects in the satellite remote sensing of land-surfaces including cultural heritage.

## 1. INTRODUCTION

### 1.1 Remote Sensing for managing cultural heritage sites

Satellite remote sensing has become a common tool of investigation, prediction and forecast of environmental change and scenarios through the development of GIS-based models and decision-support instruments that have further enhanced and considerably supported decision-making (Ayad, 2005; Douglas, 2005; Hadjimitsis *et al.*, 2005, 2006, 2007; Cavalli *et al.*, 2007)

It was found from the literature that satellite remote sensing offers many useful and sometimes essential data for the mapping, monitoring and management of world cultural heritage sites, either natural sites such as parks or cultural sites such as archaeological sites and monuments (Arnaud, 1993). By blending together satellite remote sensing techniques with GIS, the monitoring process of such sites can be efficiently supported in a reliable, repetitive, non-invasive, rapid and cost-effective way. Indeed, satellite remote sensing can assist the achievement of the following:-

- create up-to-date digital maps
- assist in the identification and precise location of sites in the world that have certain characteristics so that they could become World Heritage sites if the associated country so desires.
- help to delimitate management zones for conservation purposes
- monitor land cover changes

- assess damages caused by natural and/or human hazard.
- assist the development of stereoscopic views so as to permit and obtain a digital elevation model of the landscape or some three-dimensional measurements of monuments through the use of satellite images and ground control points (obtained from GPS). Indeed, digital maps can be better realized.
- In some areas in which an absence of recent maps of World Heritage sites exists and where such areas are often not easily accessible, recent satellite image coverage can be useful to produce new GIS layers providing the required information for a beneficial protection management of the site.

### 1.2 Importance of atmospheric correction in time series imagery

Time series of satellite remote sensed data acquired at high spatial and temporal resolution provide a potentially ideal source for detecting change and analyzing trends. Since multi-temporal images are often acquired by different sensors under variable atmospheric conditions, solar illumination and view angles, an effective atmospheric correction is required to remove radiometric distortions and make the images comparable using the retrieved true reflectance values (Mahmoud *et al.*, 2008). Several operational algorithms for relative and absolute atmospheric correction have been developed as shown by Hadjimitsis *et al.* (2004) and Mahmoud *et al.* (2008). The users of remotely sensed data must be aware about the contribution of the atmosphere to the at-satellite



signal especially in the case of time-series images. This paper addresses such issue.

### 1.3 Processing of satellite remotely sensed imagery

After remotely sensed data have been received and undergone preliminary correction at the ground receiving station, the next step is to pre-process the data. Pre-processing refers to those operations that precede the main image analysis, and include geometric and radiometric corrections. Radiometric correction is more difficult than correction for geometric effects since the distributions and intensities of these effects are often inadequately known (Hadjimitsis *et al.*, 2004), but unfortunately it cannot be neglected, particularly when multi-temporal images are to be interpreted. Techniques for correcting for sensor sensitivity changes, and for the topographic and view angle effects that are included in the radiometric correction category are well established. The most difficult step in radiometric correction is the removal of atmospheric effects.

### 1.4 Pre-processing

In the context of digital analysis of remotely sensed data, pre-processing is generally characterised by two types of data correction: (1) radiometric pre-processing which addresses variations in the pixel intensities (digital numbers, DN) and (2) geometric correction which addresses errors in the relative positions of pixels, mainly due to the sensor viewing geometry and terrain variations. Radiometric corrections are distinguished between calibrations, de-stripping approaches, atmospheric corrections and removal of data errors or flaws (Mather, 2001). Radiometric correction is more difficult than correction for geometric effects since the distributions and intensities of these effects are often inadequately known. Despite of the variety of techniques which can be used to estimate the atmospheric effect, the atmospheric correction remains an ill-determined step in the pre-processing of image data.

## 2. WHAT IS ATMOSPHERIC CORRECTION

Any sensor that records electromagnetic radiation from the earth's surface using visible or near-visible radiation will typically record a mixture of two kinds of energy (Richards, 2005). The value recorded at any pixel location on a remotely sensed image does not represent the true ground-leaving radiance at that point. Part of the brightness is due to the reflectance of the target of interest and the remainder is derived from the brightness of the atmosphere itself. For example, for an area of interest that consists of cultural heritage sites an observed digital number of 85 might be the result of target reflectance, perhaps 25, plus an atmospheric contribution, perhaps of 60 (see Figure 1). The separation of contributions is not known a priori, so the objective of atmospheric correction is to quantify these two components so that the main analysis can be made on the correct target reflectance or radiance values.

## 3. METHODS AND MATERIALS

### 3.1 Images

Archived Landsat-5 TM images of the Cyprus area acquired on the 30/01/2001, 11/5/2000, 11/9/98 and 3/6/1985 have been used (Figure 2). Quickbird image acquired on 23/1/22003 was

also used (Figure 3). The District areas of Paphos and Limassol that consist many cultural heritage sites have been selected to be used as pilot studies.

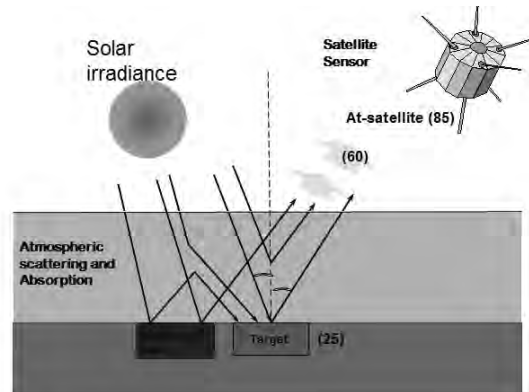


Figure 1: Atmospheric Interactions

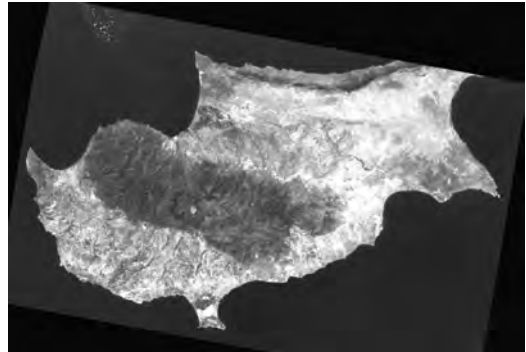


Figure 2: Landsat TM image of Cyprus (11/9/98)



Figure 3: Quickbird- 0.6m resolution image of Paphos harbour area acquired on 23-12-2003 (castle and House of Dionysos area)

### 3.2 Exploring the need for applying atmospheric correction

Two simple methods can be used to find evidence suggesting a requirement for atmospheric effects in the available imagery: image examination, and stretching

#### (a) Image statistics

Examination of the statistics of multi-temporal images (consisting several cultural sites) provides a tool for deciding

whether the images are affected by the atmosphere. Over dark bodies that located in the vicinity of cultural heritage sites any significant temporal variations of DN's (digital numbers), or any high DN's in the near infra-red (TM band 4) indicate that some images are affected by the atmosphere, since dark body has very low reflectance values in the visible bands and has negligible reflectance values at near infra-red. For example, Hadjimitsis (1999) compares the mean DN (digital number) of the same area of interest (AOI) (100 pixels) in a single reservoir for all the images, and found that large differences in DN's in bands TM 1, 2, 3 and 4 occurred. Based upon the high digital numbers found in band TM4, they concluded that atmospheric contributions were large and changed significantly from image to image.

#### (b) Stretching

Linear stretching plays an important part in the display and interpretation of digital imagery. It is one of the methods used to re-scale image brightness to ranges that can be accommodated by human vision and computer displays (Mather, 2001; Richards, 2005). A linear stretch converts the original digital values into a new distribution using minimum and maximum values specified by the user. The algorithm then matches the old minimum to the new minimum and the old maximum to the new maximum respectively. All the old intermediate values are scaled proportionately between the new minimum and maximum values (Mather, 2001). The effect of a linear stretch is to increase contrast, whilst brightening the image

In order to retrieve visual information regarding the temporal variations in the area that consist cultural heritage sites and to find evidence for the need to apply atmospheric correction the following steps were carried out on each image:

- ◆ the land was masked so that only dark bodies could be seen,
- ◆ an automatic (linear) stretch was applied to each image,
- ◆ a uniform stretch was applied to all the images, to expose temporal variations in image brightness.

Under automatic stretches the colour and brightness of the reservoirs showed significant spatial variation, but the brightness's of all the images appeared similar. When a uniform stretch was applied, however, image to image brightness variations (temporal variations) were more significant than the dark object (water body) variations (spatial variations). These temporal variations provide evidence of significant atmospheric effects.

### 3.3 Ground Measurements

The Remote Sensing and Geodesy Laboratory of the Department of Civil Eng. and Geomatics at the Cyprus University of Technology support the ground measurements of this project. Indeed, Two GER1500 field spectro-radiometers and the SVC HR-1024 have been used to retrieve the amount of atmospheric effects in different targets in the vicinity of cultural heritage sites (see Figure 4, 5 and 6). Based on the fact the landscape in the vicinity of any cultural heritage site varies from place to place, it was decided to select the following targets as pilot targets for quantifying the amount of atmospheric effects:-

- dense vegetation
- asphalt target
- sea
- lakes
- grass
- bare soil (see Figure 5)

Figure 3 shows a high-resolution Quickbird image of the castle and House of Dionyssos area in the vicinity of the Paphos Harbour area. In area most of the above target areas are apparent.

The GER1500 field spectro-radiometers are light-weight, high performance covering the ultraviolet, visible and near-infrared wavelengths from 350 nm to 1050 nm. GER 1500 uses a diffraction grating with a silicon diode array which has 512 discrete detectors and provides the capability to read 512 spectral bands. The instrument is very rapid scanning, acquiring spectra in milliseconds. The SVC HR-1024 spectroradiometer has been designed to produce excellent data, quickly and efficiently under demanding field conditions. Acquisitions through the PDA will provide GPS data for each file. The SVC HR-1024 is unmatched for high resolution field measurements between 350 nm and 2500 nm, setting a new standard within the remote sensing community.



Figure 4: GER1500 Field Spectroradiometer



Figure 5: Collection of reflectance measurements on a whitish bare soil using the GER1500 Field Spectroradiometer and the Spectralon™ White Panel.



Figure 6: SVC HR-1024 Field Spectroradiometer

### 3.4 Application of atmospheric correction

The darkest pixel (DP) atmospheric correction method, also termed also histogram minimum method was applied to the multi-series satellite images of Cyprus area since it has been found that is the most effective atmospheric correction algorithm (Hadjimitsis *et al.*, 2003).

### 3.5 Magnitude of atmospheric effects

Using the target ground measurements which were acquired from the GER1500 field spectro-radiometer a comparison was made between the at-satellite reflectance values and the associated ground reflectance values. From the time-series images, the average values of the at-satellite reflectances (%) were calculated for an area of interest in the nearby area consisting cultural heritage sites. Large variations in at-satellite reflectance values, especially in TM band 4 suggest that atmospheric effect were both variable and significant. By comparing the average at-satellite reflectance in the image time series with the ground measurements, an approximate estimate of the magnitude of atmospheric effects was found. Atmospheric effects were found to account for the following % of the received at-satellite reflectance:

- ◆ 80-90 % in TM band 1,
- ◆ 40-70 % in TM band 2,
- ◆ 50-80 % in TM band 3,
- ◆ 90-95 % in TM band 4.

## 4. CONCLUSIONS

Two methods of obtaining evidence for the need to apply atmospheric correction in the satellite images have been presented. An overview of the magnitude of the atmospheric effects in satellite imagery of cultural heritage sites in Cyprus have been presented by comparing at-satellite values with ground measurements. It can be seen that atmospheric affects can be both large and variable. It is therefore essential that they are taken into account before attempts are made to ground conditions on the basis of multi-spectral reflectance values. In the management of cultural heritage sites, since temporal satellite images are required for monitoring purposes, the effect of the atmosphere must be considered

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## THE HARRIS MATRIX COMPOSER - A NEW TOOL TO MANAGE ARCHAEOLOGICAL STRATIGRAPHY

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**KEY WORDS:** Harris Matrix, Archaeological Stratigraphy, Excavation Management and Analysis

### ABSTRACT:

The Harris Matrix - formulated by Dr. Edward C. Harris in 1973 - is the established way of representing the archaeological stratigraphy of an excavation. The Harris Matrix is a sequential diagram defining relations between stratigraphic units. It is an important method to document the stratification that is destroyed by the excavation process and hence a vital tool for analysis. Although the Harris Matrix has become a quasi standard of archaeological stratigraphy, only a few software tools exist to create and edit these diagrams. An evaluation of these tools showed that they do not completely comply with the theory or suffer from poor usability. Therefore we decided to develop a new application, called Harris Matrix Composer (HMC). Dr. Harris was involved in the evaluation of early prototypes to guarantee compliance with his theory. User tests were undertaken to address usability problems. The HMC provides a graph editor with an intuitive graphical user interface for editing a Harris Matrix throughout the entire excavation process. It supports valid Harris Matrix creation and indicates invalid units and relations. The theory has been extended to allow for temporal relations as well. Furthermore units can be grouped into structural entities called phases and into periods, assigning them to a historical epoch. A powerful interface to the GIS system ArcGIS will be developed to access layers for visualization and analysis by selecting units of the Harris Matrix. In this way the HMC becomes also a unique tool for the management and retrieval of digital archaeological data.

## 1. INTRODUCTION

### 1.1 Archaeological Stratigraphy

Every archaeological site is stratified and any archaeological stratification is unique. Stratigraphy, the description and interpretation of stratification, is the main key for any further analysis of archaeological finds. Excavation is both costly and destructive. The recording process, which takes place during excavation aims at dividing the stratification into its components, the units of stratification. This is done by removing single deposits in the reverse order to which they were formed. Any unit of stratification has to be destroyed as the excavation proceeds to the next one. It is therefore absolutely necessary to document each stratification unit by recording its physical and spatial properties and stratigraphic relations, while collecting finds and samples in relation to it as accurately as possible (Neubauer, W., 2007).

The stratigraphic excavation method, as defined by E.C. Harris (Harris, E.C., 1989) makes it possible to record the single units of stratification (i.e. deposits and surfaces) along with all its attributes and relations, and to create a stratigraphic sequence from this data. Such a sequence is known as Harris Matrix (Figure 1). As Harris points out, every unit of stratification is formed by material (deposits) and immaterial aspects (surfaces or interfaces) that have to be found and recorded by the excavating archaeologist.

In the first instance these two aspects are the main objects to be recorded on a stratigraphic excavation. Any finds, samples, or other information and observations have to be related to the deposits and surfaces, i.e. the units of stratification, for the subsequent analysis.

The Harris Matrix is the fundamental diagrammatic representation of time for an archaeological site. It displays all uniquely numbered units of stratification in a sequential diagram, which represents their temporal succession. It provides the relative calendar which is the testing pattern for any further analysis.

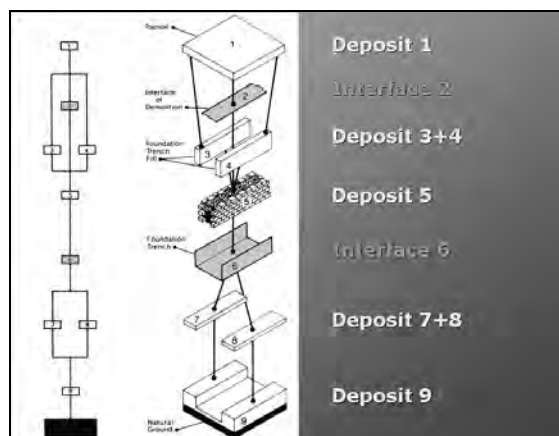


Figure 1: Creation of a stratigraphic sequence as defined by E.C. Harris 1989.

### 1.2 Stratigraphic Recording

Terrestrial laser scanners combined with digital imagery are the most effective tools for stratigraphic recording to date and provide the ability to reconstruct the excavated volumes and specific surfaces in 3D space (Neubauer, W., 2007; Doneus, M. & Neubauer, W., 2005a). Therefore, 3D recording of the top and the bottom surface of any single deposit, as well as the 3D

recording of specific interfacial surfaces is necessary to reconstruct fully any part of a site destroyed during the process of excavation (Neubauer, W., 2008a).

Figure 2 (left) shows the terrestrial laser scanner Riegl LMS Z420i on scanner platform (Riegl, 2008) at 4.5 m height monitoring the stratigraphic excavation process at Schwarzenbach, Austria (Doneus, M. & Neubauer, W., 2005b). Figure 2 (right) shows the triangulated and textured virtual model of four successive top surfaces of excavated deposits and scatter of categorized finds spots.

During recording every single unit – surface or deposit – is given a unique number and documented by its boundary polygon, as well as its topography. The collected point-clouds from specific surfaces, the surfaces of deposits and the associated texture derived from digital photographs are the primary raw data and processed in a Geographical Information System (GIS). In that way the geo-referenced data is immediately available for on-site analysis (Neubauer, W. & Doneus, M., 2008).

Surfaces, the immaterial aspect of stratification, can therefore be captured in their entirety. By their nature, the material aspects of deposits can only be captured by sampling. For the stratigraphic record, each deposit, as represented by its top and bottom surface is reduced to a unique number in the Harris Matrix. It imparts this number to all of the portable finds and samples found within its volume. Their 3D position can be easily defined upon discovery or extraction. All additional attributable data, such as descriptions of surfaces and deposits and the finds database are integrated into the GIS.



Figure 2: Recording of surfaces with a laser scanner.

### 1.3 Creating and Editing a Harris Matrix

As GIS provides the ability to store, visualise and analyse graphical information in combination with descriptive information, it is a perfect general tool for the visualization and analysis of excavation results. The outstanding value of a GIS is its ability to reproduce the complete record of a stratigraphic surface as well as any related descriptive information (Doneus, M., Neubauer, W., Studnicka, N., 2003; Harris, E.C., 2001).

The stratigraphic recording of an excavation as described above results in a vast volume of digital archaeological data. This data needs to be ordered by setting the correct stratigraphic relations. GIS do not provide such a feature. Usually it just allows arranging data sets into a tree-like hierarchy that has nothing to do with stratigraphic relations.

The Harris Matrix is de facto the standard method of defining stratigraphic relations. Thus a tool is needed that allows creation and editing of a Harris Matrix during stratigraphic recording. This tool can then be used to provide the GIS with

the necessary stratigraphic relations and to manage digital archaeological data stored by it in a meaningful way for analysis.

Since no tool is available that completely complies with the theory of E.C. Harris (Harris, E.C., 1989), let alone provide an interface to GIS, we decided to design and develop a new one, which is called Harris Matrix Composer (HMC). This project paper describes the requirements on the HMC, the resulting design of its user interface and evaluation results.

## 2. REQUIREMENTS FOR A HARRIS MATRIX TOOL

Requirements have been acquired in close cooperation with archaeologists. Reported experiences with other tools have been taken into account (see next section). The practice of documenting stratigraphic relations by other means has been studied in the field, observing archaeologist on excavation sites. This revealed that a standardized method has not yet prevailed. People were filling lists of stratigraphic relations either with standard text editors or on printed templates. If these lists were later translated into Harris Matrices at all, it was done by using diagram editors or by pen and pencil, - a clear sign that an appropriate tool is still missing.

The creation of a Harris Matrix has in fact to parts. The first stage is the creation of a correct stratigraphic sequence. Units of stratification are either deposits or surfaces. Each excavation is enclosed between the top surface and the interface to geology, marking the start and end of the process. The first stage is based entirely upon the analysis of the topographical record and topology by defining the stratigraphic relations “above” and “below” or “none”. The first stage is finished right after the excavation.

The second part is the division of the sequence into so called phases and periods. It depends on additional information based on structural (phase) and temporal (period) analysis of the stratigraphic record. The first stage can be done during the excavation and is not related to any find analysis. The Harris Matrix can be created without any respect to the archaeological finds. They have to be integrated in the second stage when the units of stratification are grouped according to structural or temporal arguments into phases and periods.

The creation of a Harris Matrix does not consider any temporal relations between units that might be deduced from related finds in the subsequent analysis. Stratigraphic relations imply temporal relations. But it is not possible to explicitly set temporal relations between stratigraphical unrelated units. So we proposed to extend the theory by incorporating the temporal relations “later” and “contemporary”. This has been discussed with E.C. Harris and he liked the idea.

One of the most important requirements concerns usability. The tool should provide an efficient way of building up a Harris Matrix during stratigraphic recording. This implies a Graphical User Interface (GUI) that is intuitive and easy to comprehend. Familiar and well established paradigms of interaction as known from widely used drawing tools need to be considered.

The Harris Matrix is created by direct manipulation. Thereby the user should be freed from the task of doing a layout. The tool should automatically arrange the graph structure according to the theory. Most important is that the layering of units, which

determines their vertical arrangement, reflects the stratigraphic sequence and thus their temporal succession. This means that all lines representing the relation “above” point from top to bottom connecting two units on different layers, which correspond to different time slots. The same is true for lines representing the temporal relation “later”, while lines representing the relation “contemporary” are bi-directional horizontal lines, because they connect units that are placed on the same layer, i.e. belonging to the same time slot.

Usually a Harris Matrix quickly becomes very large, so that sophisticated navigation methods are essential. It is necessary to zoom and pan efficiently but also provide a mechanism to jump and focus to a certain unit, phase or period. User tests with early prototypes revealed that a search function is desired. The tool should also be able to remember the locations in the matrix that has been most recently edited.

A pedagogical requirement has also been identified. The tool should support its users to create valid Harris Matrices that fully comply with the theory. Invalid relations, like cycles and invalid units, like those with missing relations are indicated and an explanation is given. This validation check helps students to better understand the concept and strengthens learning by doing. In that way it should also help to spread the method of stratigraphic excavation. The validation check is also an aid for professionals showing them mistakes or missing input. However it must not hinder users to proceed with building the stratigraphic sequence but just give them a hint that there is something to resolve to obtain a valid Harris Matrix.

The HMC needs to incorporate a direct interface to a GIS. The matrix then will be used as a GUI for the creation of composite maps and 3D reconstructions of phases and periods. Such reconstruction has often been impossible to achieve on most archaeological sites until the introduction of the Harris Matrix and the advent of GIS technology. So it is an important and valuable requirement to combine the Harris Matrix concept with GIS technology.

Concerning system requirements, the HMC needs to be computational efficient with a low memory footprint. This is because the tool will be mostly used in the field running on lightweight mobile computers. Despite that fact it must be able to handle the large graph structure of a typical Harris Matrix. It also needs to be robust and reliable. When the system crashes most of the data must be retrievable. Platform independence has been identified as desired property.

### 3. EVALUATION OF EXISTING TOOLS

One of the first Harris Matrix tools was included in the BASP package (Scollar, I., 1994; Scollar, I., 2008), a software bundle for archaeologist. The user interface is outdated. Stratigraphic units and their relations can only be defined by textual input. Then the tool draws a Harris Matrix with a suitable layout that can be controlled by some parameters.

Direct manipulation is not supported and so creation and editing becomes a tedious task because it is necessary to switch between the input mask and the visualisation. The tool was also restricted in the amount of data it can handle.

Because of those limitations the tool Arched was later developed based on the algorithms of the BASP Harris Matrix tool (Pouchkarev, I., Thome, S., Mutzel, P., Hundack, C., 1998;

Hundack, C., Mutzel, P., Pouchkarev, I., Thome, S., 1997). ArchEd had a standard GUI and the Harris Matrix is created and edited by direct manipulation. It provides layout algorithms that can be configured.

Although ArchEd is a good approach and a clear improvement to the BASP tool, it misses to meet some of the requirements described in section 2, which are:

- It does not distinguish between the two types of stratigraphic units, surfaces and deposits.
- The top surface and interface to geology, thus the start and ending point of any valid Harris Matrix are not considered.
- Stratigraphic units cannot be assigned to phases and/or periods.
- Temporal relations are not represented in the graph structure but only as text indicators in symbols of units.
- Validity of the Harris Matrix is not checked.
- It has no interface to a GIS.

The last version of ArchEd (v1.4) was released in 2004 and since then development has been frozen. We first considered building upon ArchEd and implementing missing features. But analysis of the requirements convinced us that it is better to start from scratch. We also decided to use a professional Java library for graph drawing enabling us to develop an intuitive GUI in reasonable time.

Another well known Harris Matrix tool is Stratify by Irmela Herzog (Herzog, I., 2008). Its major drawback is that direct manipulation is not supported and display methods based on graph theory is emphasized (Herzog, I., 2004; Herzog, I., 2006). Units and their relations have to be inserted into lists from which a Harris Matrix is created. Layout techniques are sophisticated, making it possible to arrange the Harris Matrix in a way that omits or minimizes crossing of lines. Grouping of units to an arbitrary depth is supported. However, we have not identified this as an important requirement and it can easily be confused with phases and periods, which seems to provide sufficient hierarchical ordering.

Stratify focuses on chronologic relation alone. So it does not distinguish between stratigraphic and temporal relations. This is confusing because the first are established by the excavation alone and the second by analysis of the stratigraphic record. The software also seems to misinterpret the meaning of phases. It defines phases by vertically separating units, i.e. assigning them to different layers. This however is characteristic for periods, whereas phases are a structural combination of units. Phases can be contemporary with each other and then they lie on the same layer. On the other hand Stratify allows colour coding units according to the period they belong to.

Beside that Stratify does not meet some of the key requirements. It also does not distinguish between surfaces and deposits. Hence the top surface and interface to geology are not considered. And it does not provide an interface to a GIS.

## 4. DESIGN OF THE HMC

### 4.1 The Graph Editor

The heart of the HMC is the graph editor, where the Harris Matrix is composed (see Figure 3). It starts with a minimal but valid Harris Matrix, consisting of the top surface, the interface to geology and a special unit called “Unexcavated” that represents the unexcavated archaeological stratification. As long as this unit cannot be deleted without invalidating the Harris Matrix the stratigraphy is not finished.

Users add either deposits or surfaces by choosing the appropriate tool from the toolbar and clicking somewhere on the background of the graph editor. The new units automatically move to the top layer and build a sequence there, like birds on a wire. This is because their final position depends on their stratigraphic relations, which have yet to be set. Each unit of stratification except the preset top surface and the interface to geology must be set in stratigraphic relation with at least one unit above and at least one below it to be valid. As long as these relations are not set these units are marked as invalid.

To set stratigraphic relations the users draw a line with an arrow head between two units. This line represents the relation “above” and means that the unit where the line starts lies above the unit where the line points to. There is no extra tool for the relation “below” because for that the line only needs to be drawn in the opposite direction. Most invalid relations are recognized as they are drawn and declined, for example if a user tries to set a unit above the top surface. An explanation is then given in the status bar.

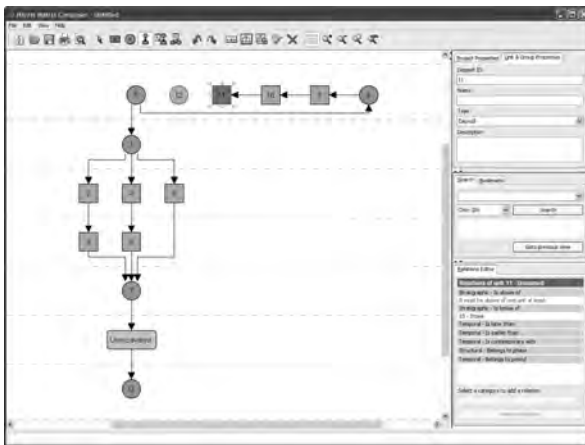


Figure 3: Composing of a Harris Matrix with the graph editor.

Other invalid or impossible relations are only recognized by analysing the whole Harris Matrix, which does not work in real time. This especially concerns transitive and cyclic lines. Users can trigger a validity check whenever they like. The Harris Matrix is then analysed using methods from graph theory. Transitive lines are automatically removed, i.e. if unit A lies above unit B and B above unit C then the relation “A above C” is transitive and redundant.

Cycles represent a physically impossible stratification because when unit A is above unit B and B above C then C cannot be above A. Cycles are detected by the validity check and the corresponding lines are marked as invalid (see Figure 4). This is

a clear composing mistake and needs to be resolved by the user since the application cannot know, which line in the cycle the wrong one is. An exception are loops to the same unit, which are declined in real time and cycles between two units, in which case the direction of the line is reversed, i.e. when A lies above B and the users draws a line from B to A then this line is kept and the one from A to B is automatically removed.

The Harris Matrix can be set into a layout that complies with the theory. All units are then moved to the layer that corresponds with their stratigraphic relations. This means that all lines are vertical lines pointing from top to bottom as one would assume for the lines representing the relation “above” (see Figure 5). The layout algorithm can only be applied to a valid Harris Matrix. It cannot resolve invalid units that have missing relations or cyclic lines. Therefore validity check and layout are combined to one function.

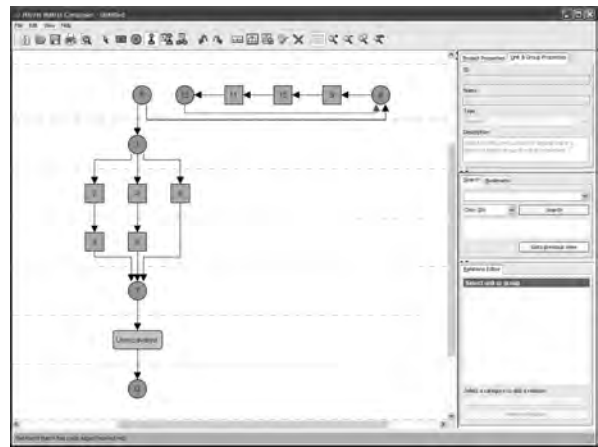


Figure 4: A cycle has been detected by the validity check and marked red.

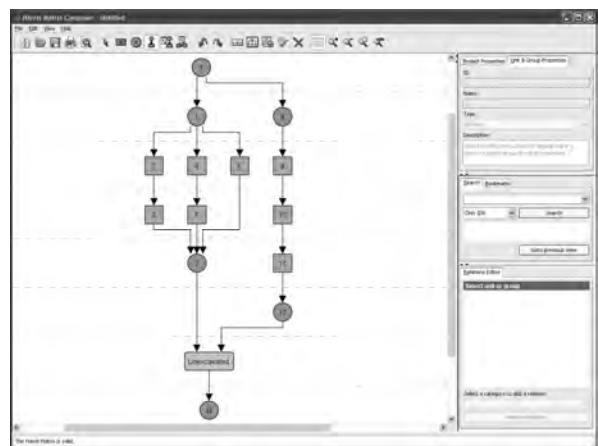


Figure 5: A valid Harris Matrix in the correct layout.

### 4.2 Temporal Relations

As mentioned in section 2 we extended the theory to allow explicit temporal relations. Stratigraphic relations imply temporal ones. But analysis of the stratigraphic record might yield additional, non topological arguments to define extra temporal relations between units. Users can either set a source

unit to be later than a target unit or set both units as contemporary. The relation “earlier” is obtained by drawing a “later” line in the opposite direction.

Temporal relations are represented by dotted lines in a different colour. Lines meaning “later” point to the unit that is earlier than the one the line originates from. Contemporary is a bi-directional relation shown by lines with arrows at both ends (see Figure 6).

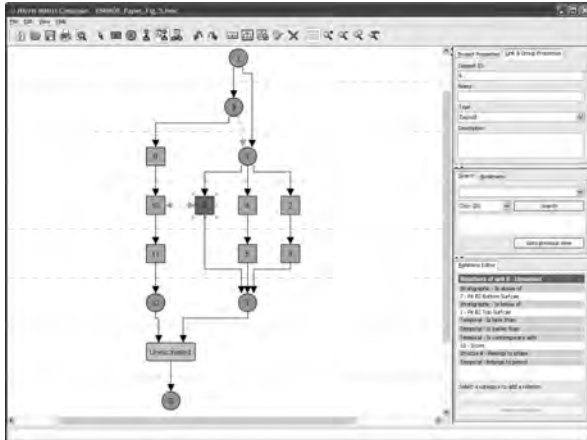


Figure 6: A Harris Matrix with temporal relations “later” and “contemporary”.

Temporal relations are considered for validation and layout. They can be transitive with respect to themselves but also with respect to stratigraphic relations. Any stratigraphic relation “above” also implies the temporal relation “later”. Temporal relations that are transitive in one or the other way are removed by the validity check. For example when unit A is above B and B above C then the relation “A later than C” is redundant and removed.

The temporal relation “later” has similar effects on the layout as the stratigraphic relation “above”. It positions units on appropriate layers so that these lines always point from top to bottom. In contrast contemporary units are placed on the same layer so that the lines representing them are horizontal.

Like with transitivity, cycles can be caused by temporal lines with respect to themselves and to stratigraphic lines. For example if unit A is above B and B above C then C cannot be later than A. To be consistent first stratigraphic relations are checked independently and then temporal relations are checked considering also stratigraphic ones. Temporal lines can also be hidden by the user so that only stratigraphic relations are seen. In that case they do not affect validity checks or the layout.

### 4.3 Phases and Periods

During analysis of the stratigraphic record units might be assigned to a structure and/or to a period as described in section 2. User can select units and group them into a phase, which represents a structural entity, for example post-holes remaining from an ancient dwelling. Phases cannot be nested but can belong to periods.

Periods represent a certain historical epoch. Units and phases are assigned to a period by selecting them in the Harris Matrix

and use the appropriate grouping operator. Periods cannot be nested and encompass units that lie on different layers since the vertical position also has a temporal meaning. In the current design neither phases nor periods can have any relations. They are solely defined by the stratigraphic units they contain.

Both phases and periods appear as boxes that encompass the items grouped into them (see Figure 7). These boxes can be collapsed one by one or all at once to make the Harris Matrix more compact. When collapsed their content is not shown and the group appears as small box with a label (see Figure 8). Of course each collapsed group box can be expanded again.

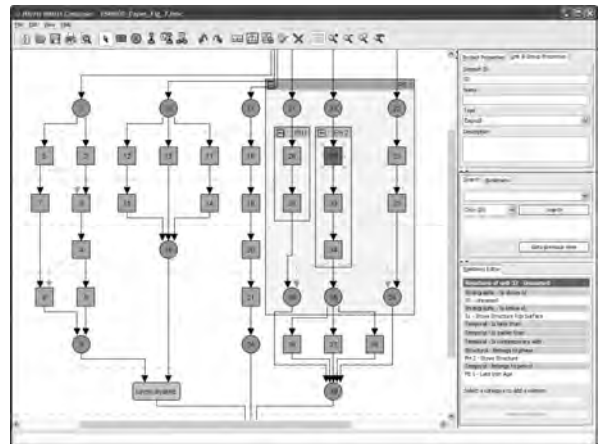


Figure 7: A Harris Matrix with phases and periods.

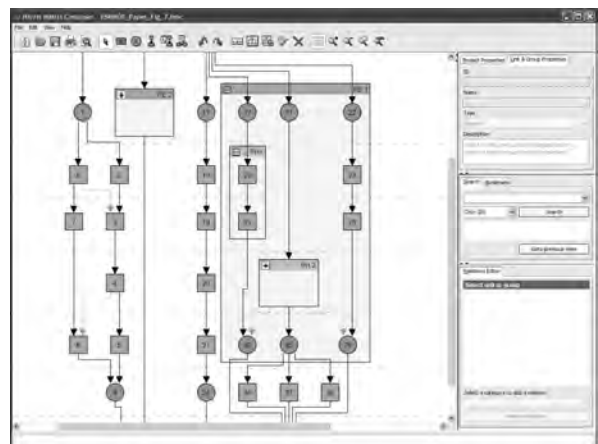


Figure 8: Collapsed phase and period boxes.

### 4.4 Navigation

A typical Harris Matrix is rather large. Hence efficient and convenient navigation techniques are important. There are two types of navigating through the graph structure, by direct manipulation of the graph view and by searching for units and jumping to bookmarks.

Direct navigation is achieved by panning and zooming. Panning works by dragging the mouse, which is analogue to shifting a sheet of paper with the hand. Zooming is done by the mouse wheel. Users can rapidly change to a completely different view by resetting the zoom factor so that the whole Harris Matrix is



shown and then use a tool to draw a frame around that part, which should be magnified to the window's size.

A full text search can be initiated by the search panel. All the data associated with units can be searched, i.e. its id, name and description. A list of results is shown and when clicking on an item the view of the graph smoothly changes to the found unit, so that it appears in the centre in normal size.

A view can also be bookmarked and later looked up in the bookmark panel. In this way users can store interesting points or locations that are currently edited and efficiently jump between them.

#### 4.5 The Properties Panel

The project properties editor of this panel allows naming the project, writing a description and referring to the excavation site. When a unit is selected in the Harris Matrix the panel automatically shows the unit properties editor. Here the unique identifier of units can be changed. It is set automatically while composing by using consecutive numbers. The application refuses to change the identifier if it is not set to a unique alphanumeric value. This is important because it is used for the interfaces to GIS or external database.

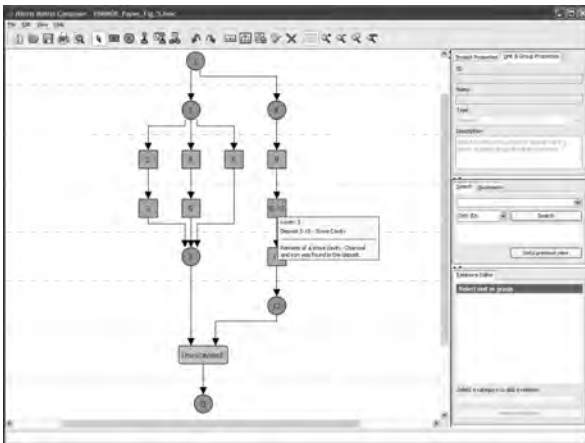


Figure 9: Properties set in the properties editor are shown in a pop-up balloon, when the mouse is moved over a unit.

Other properties for units are a name, a description and its type, namely either deposit or surface, which can also be changed by this editor. The unique id appears as label of the graphical representation of units in the graph editor. All other properties appear in a balloon when moving with the mouse over a unit (see Figure 9). Phases and periods can also be assigned a unique id, a name and a description by selecting them and using this editor.

#### 4.6 The Relations Editor

This panel lists all relations of the selected unit, phase or period (see Figure 10). It provides an additional view beside the graph structure in form of a list. Beside the relation "above" it shows also the relations "below", which is defined implicitly, i.e. when A is set to be above B then B is implicitly set to be below A. In addition it also lists all temporal relations including "earlier" as complement to "later" and "contemporary". If the

selected unit belongs to a phase and/or period then they are also shown.

The relations editor provides an alternative way to set relations. For each relation category a unit can be chosen to establish the corresponding relation between the selected unit and the chosen one. The corresponding line is then immediately drawn in the graph editor. It is also possible to delete relations in which case the corresponding line is removed. The selected unit can also be assigned to an existing phase or period by choosing it from the drop down list.

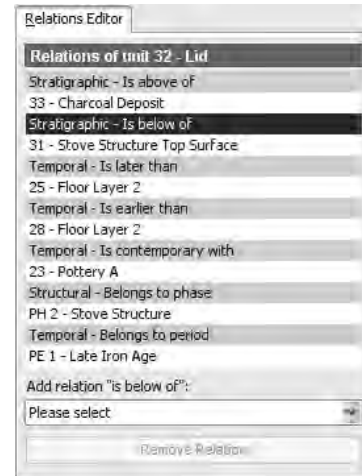


Figure 10: The relations editor showing all relations of the selected unit.

#### 4.7 Management of Digital Archaeological Data

The HMC needs an interface to a GIS to select digital strata for visualisation and analysis. There are two ways of realising this feature. One solution is to use the HMC directly. On demand of the user it communicates with the GIS, sending selected units to it. The GIS then selects the corresponding data for visualisation.

Another solution is to derive a plug-in from the HMC that directly runs in the GIS to access digital archaeological data. It then provides an alternative to the common tree view. In that case it first loads a Harris Matrix composed by the HMC. The plug-in provides features for navigation and selection but does not allow manipulating the Harris Matrix.

### 5. IMPLEMENTATION AND EVALUATION

The HMC is a Java application and hence platform independent. We decided to use the very powerful Java library "yFiles" from yWorks (yWorks GmbH., 2008). It provides methods for graph editing and visualization including various layout techniques. Special classes have been designed and derived from yFiles classes to implement all the required Harris Matrix functions.

The HMC was developed by rapid prototyping. That strategy alternates between development and evaluation in several cycles. Every new version of the prototype is evaluated in user tests and the analysis of these tests guides the next phase of development. Because of our project consortium we were able to test even early prototypes on target groups, professional

archaeologists and archaeology students. This was especially important to improve the usability of the tool.

One of the prototypes was also demonstrated to Dr. E.C. Harris in a small workshop in September 2007 in Bermuda, where he resides. We were glad that Dr. Harris liked our prototype very much and recommended to protect the software, which we did. We had the pleasure to discuss and refine theoretical aspects of the Harris Matrix together with its inventor. This especially concerns the extension for temporal relations, and the grouping of units into phases and periods. So the HMC fully complies with the outcome of this discussion and the theory of Dr. Harris.

The first beta version of the HMC was evaluated in a field trial for a real excavation project in Schwarzenbach, Lower Austria (Neubauer, W., 2008b). It was also used for a lab course on archaeological stratigraphy at the University of Vienna. Both tests brought new insights and revealed usability issues, which have been addressed in the following development phase.

A free trial version (beta 1.1) is available for download at the HMC website "www.harrismatrixcomposer.com". This free version is restricted to 50 stratigraphic units. Not all designed features are yet implemented. A full version will be available in November 2008.

At the time when this paper was submitted (June 2008) approximately 400 users have downloaded the free trial version. We already received valuable feedback from them, which helps us to further improve the HMC. Beside that a next large field trial is planned.

## 6. CONCLUSION

With the HMC a new tool for the composing and editing of a Harris Matrix has been introduced to the archaeological community. We are glad about all the positive feedback and the constructive comments we received so far. The strength of the HMC lies in its full compliance with the theory, which has been achieved in collaboration with its inventor Dr. E. C. Harris.

Another aspect is its usability, which was evaluated from the very beginning by successive user test on early prototypes. The interface to GIS makes the HMC to the ideal application for the management of digital archaeological data and thereby closes a gap in the software toolbox for archaeologist. The HMC will be directly used to access data in the GIS for visualization and analysis by selecting stratigraphic units in the Harris Matrix.

Further feedback of users and field trials will improve and extend the HMC so that a reliable and robust tool emerges. We hope it will gain high acceptance in the archaeological community. We also think that it is very well suited for the training of students in courses and labs. If so, it will foster the practice of stratigraphic excavation.

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# COMPREHENSIVE LOW-COST DOCUMENTATION OF BUILT HERITAGE USING SOCIAL NETWORKS, OPEN SOURCE SOFTWARE AND RICH INTERNET APPLICATIONS

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**KEY WORDS:** Built Heritage, Low-cost Documentation, Local Social Networks, 3D modelling, Geospatial referencing, Open Source Software, Rich Internet applications

## ABSTRACT:

Built heritage in many countries is at risk and disappearing. Comprehensive documentation of sites is essential before there is further loss. 3D laser scanners, GPS and EDM equipment used by professionals is expensive and time-consuming. This is not a viable solution for mass documentation, particularly in developing countries. It is shown that high volumes of documentation at low-cost can be achieved with a comprehensive solution using local social networks, open source software, and rich internet applications. The solution includes local part-time field researchers, recruited using Internet social networking techniques, who collect the data, and a small core team that checks, edits and enhances the data. The paper describes processes that use open source software for restitution of 3D models from images, and for creating and editing geospatial data. Rich Internet applications (RIA) that enable very interactive user experiences in browsers are used for graphical geographical and timeline searches in the web-based documentation repository. With RIA technologies and open source software, user forums and contributions are expeditiously implemented and managed. The initial development and implementation costs of the web-based portal and repository are low. When the local social networks and users reach critical mass, the data collection process and repository can be sustained with very low operating expenditures.

## 1. INTRODUCTION

Documentation is an essential component of research, preservation and restoration of built heritage. Documentation provides a record for posterity, especially when a site is damaged or lost.

That sites are being lost is an established fact. Well known sites that have recently sustained damage or loss include the Sungye Gate (Namdaemun) in Korea (Associated Press, 2008) and the al-Askari mosque in Samarra, Iraq (BBC News, 2006). How many lesser known but culturally and historically significant sites have been damaged without recognition or knowledge? While the losses may never be quantified, it is certain that much has been already lost.

### 1.1 State of Built Heritage Documentation

In developed countries, there are private and government organizations for documentation and preservation. Examples include Historic American Buildings Survey (HABS) and Cultural Resources Geographic Information Systems (CRGIS) in the USA, Council of Europe initiatives and guidelines in the European Union (including Michael, Minerva and EPOCH initiatives) and English Trust (public) and National Trust (charity) in the UK.

In other parts of the world the story is not positive. Due to lack of resources very little documentation apart from that for the most famous sites has been realized.

High definition documentation processes using laser scanners, GPS receivers and surveying instruments are expensive, require professional skills (usually not local) and are time-consuming.

It is essential to record and document thousands of sites in the developing world before further damage or destruction. This

can only be done if the process is low-cost and reasonably quick.

### 1.2 Comprehensive Low-cost Documentation and Distribution Solution

With a full functionality device such as the envisioned Ridjigital Documatic (Ogleby, 2004), comprehensive mass documentation would be possible; but how can documentation of disappearing built heritage be intensified and expanded before such devices are manufactured?

A comprehensive solution that incorporates local resources for data collection, open source software for processing, checking and enhancing the data, and use of rich internet Web 2.0 applications, provides a global web-based portal and repository that is scalable for growth and open to all.

## 2. DOCUMENTATION CONTENT

The solution facilitates collection and creation of comprehensive records. The contents of the web-based documentation repository and portal are listed below.

**Core content:** The content for each heritage site consists of basic data that follows the *Core Data Index to Historic Buildings and Monuments of Architectural Heritage*, approved by the Council of Europe (Council of Europe, 1995). Core data gives a summary of the site's characteristics and these elements are used in performing flexible database searches and queries.

**3D models:** Useful 3D geometric models are restituted from photographic images. With recently derived techniques and software (Vergauwen and Van Gool, 2006) and the use of simple guidelines for taking photographs (Vergauwen, 2007), good quality 3D models are generated.

**Geospatial point and area coordinates:** The geographical coordinates of a site's location are essential for mapping and geospatial information systems. Coordinates are also necessary for geospatial or map-based searches.

**Style and time periods:** The architectural styles, historic periods and temporal periods of the building are specified.

**History:** The history of the site and its location is presented in summary and in detail. The detailed history is usually presented via links to reputable web sites or references to other resources.

**Contextual Narrative:** The populations around the sites have knowledge of the historical and cultural narratives involving the sites. This includes legends, use, and how the site influences the community. Local researchers obtain this information by interviewing the neighbouring population, when it is viable and safe.

**Images:** This category consists of photographs of the built structure taken by local investigators, contributions by registered portal users, and links to other web sites with images related to the structure. Images include both exterior and interior views, and photographs taken for 3D models.

**Architectural Elements:** Unique and significant architectural and structural elements of sites are recorded using photography, sketches or drawings. Examples of such elements include arches, domes, ceilings, columns, muqarnas, parapets, stupas, geometric decorative patterns and structural frameworks that are either unique or define a particular architectural style.

**Resource links:** Published and online work on documented sites is recognized and referenced. There are links to related online web pages and sites, and citations for published references.

**Education and Learning:** Special student sections are created for topics that are of interest to younger learners in history, geography, art and architecture. Affiliations with educational institutions and educators are established on an ongoing basis, the educators doing a portion of the work to create appropriate supplementary content with guidance from project personnel. There is vast potential to expose students to history and culture, their own and that of others, through study of built heritage.

**Community Participation:** Participation in discussion threads and contribution of user material is open to all. Distinction is made between contributions of the project team (field researchers and core team) and contributions of the community.

### 3. SOCIAL NETWORKS

Social networks and "user generated content" have had tremendous growth and impact in the last five years, as seen in sites such as Flickr, Wikipedia, OpenStreetMap and ArchNet. These networks, some with monitored content, have created remarkable online resources.

Flickr is a site for managing and sharing digital photographs. Many of the photographs are tagged by the people who upload them with keywords. Millions of the photographs are georeferenced, or *geotagged*, as well. Flickr was launched in February 2004 and it had hosted more than 2 billion images by November 2007 (Arrington, 2007).

Wikipedia, one of the most popular web sites, was created in 2001 and has over 10 million articles in 250 languages by more than 75,000 active contributors. It is the largest reference site on the web and has 684 million visitors a year (Wikipedia, 2008).

OpenStreetMap is a project to create free, editable maps. It was founded in July 2004, uses the web for collaboration, data collection and editing. As of June 2008, there were over 40,000 contributors who had uploaded over 300 million GPS points describing roads, motorways, railways, tracks and other geospatial objects (OpenStreetMap, 2008). The map data is available under the Creative Commons Attribution-ShareAlike 2.0 license.

ArchNet is a databank of international and Islamic architecture. The online library made up of photographs, line drawings, CAD drawings, published papers, video, and text resources, was started in 2000. There are contributions from schools of architecture and individual collections. It is open to all and has over 50,000 active users.

#### 3.1 Local Networks

A major component of the low-cost solution is the use of local networks: social networks of field researchers who are located close to the sites, have Internet experience, collect the data and add local knowledge.

The local field researchers are recruited over the Internet with postings at sites and bulletin boards related to built heritage and architecture, as well sites such as Craigslist.org, that features free classified advertising in many countries around the world. Internet recruiting is important as many of the data collection tasks – training, communicating with peers and project managers, data file transmission – require familiarity with the Internet.

The types of data collected by the local networks include digital photographs for recording architectural elements and for generating 3D geometric models. Geospatial area and point locations are recorded with web-based or open source tools. Cultural context of the site is obtained by interviews with the local population or authorities. Local archives and libraries may have useful documents related to the heritage site. When permission is granted, copies and scans are made of these documents, providing this activity does not damage or alter the documents.

Local researchers are provided training in the collection of site data. The collection process does not require professional expertise in surveying, photogrammetry, archaeology and geospatial systems.

Data is collected in the field by multiple field researchers working at several sites simultaneously. One field researcher per site is sufficient in most cases. Project management, training, quality checking and enhancement are performed by a small core team with the appropriate skills.

The core team activities include generation of 3D models from images and checking and loading of the geospatial data from field researchers into the repository database. The core team loads core data index and timeline data. The team edits history and cultural context narratives for the web site.

All image and geospatial data is transmitted from local researchers to core team by means of email or Internet file transfer utilities (FTP). Transcripts of cultural narrative interviews are also sent by email. Copies or scans of local documents, when available, are transmitted over the Internet or by post.

Training is performed over multiple web channels: wikis for documentation, email for interactive communication, and group training using voice-over-IP.

Figure 1 shows tools and applications on the Internet that enable social networking and collaboration between disparate field researchers and between the core team and field researchers.

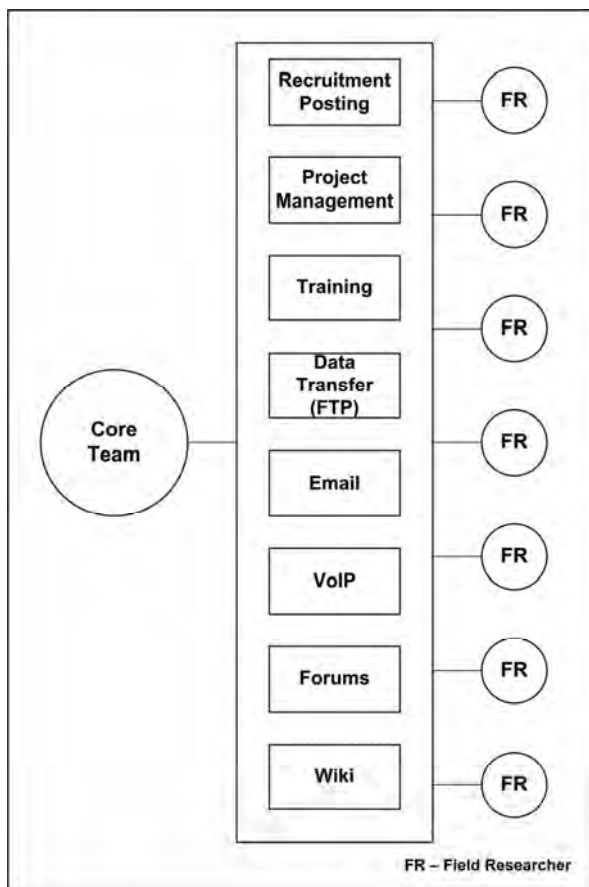


Figure 1: Social Networking tools for recording heritage

### 3.2 Online Community Participation

The web portal and repository will create a worldwide community that contributes to heritage documentation and participates in using the documentation. It is open to all, professionals, interested public, teachers and students. To contribute content and to participate in discussion forums, participants must register, providing name, email address and professional affiliation. Email addresses are not divulged unless requested. Contributions from the community are identified as such and appropriately attributed. Portal administrators and/or moderators from the user community regularly monitor the contributed content and flag or remove inappropriate material.

## 4. OPEN SOURCE SOFTWARE

Software tools are used in most aspects of the web-based documentation repository: data collection, data checking and editing, data enhancement and presentation. Open source software tools are employed in all these cases.

Open source software provides flexibility and keeps the cost of implementation low. If necessary, modification of software is achievable. The development teams are accessible and direct communications and collaboration with them is common and accepted part of the open source culture.

### 4.1 Software for data collection and enhancement

Data collected by the local researchers is checked, edited and enhanced before uploading to the web-based repository.

3D geometric models of buildings are created from digital photographs. Photographs must be taken from appropriate distance and angles (Vergauwen, 2007)—this is part of the training. ARC 3D is used to convert the images into point cloud models. Meshlab is used for viewing 3D models, and cleaning point clouds. ARC 3D and Meshlab are part of EPOCH network tool set (EPOCH, 2008).

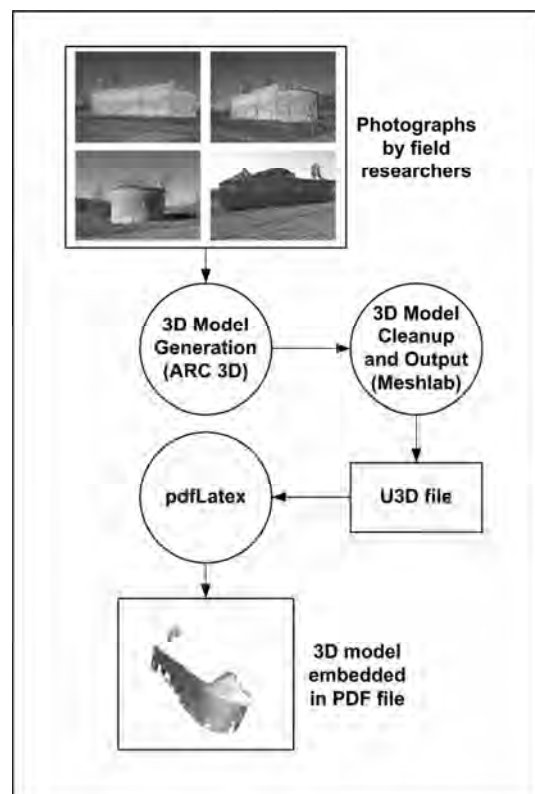


Figure 2: 3D model generation

Universal 3D format (U3D) models from Meshlab are used for generating PDF files with embedded interactive 3D objects. These files allow 3D viewing of a model using the standard Acrobat Reader (versions 7 and higher). pdfLatex, an open source application, enables creation of embedded PDF files.

From the portal site, users can download the embedded PDF file, or the U3D file, or both.

Geospatial information for a historical-cultural site is in several forms. It can be polygons describing the area of a site, points showing the location of specific buildings, or line segments that describe a path. Figure 3 shows examples of polygon and point elements.

Geospatial coordinates are entered by local researchers using web mapping tools including Google Earth, Google Maps or Microsoft Live Search Maps. The data is transmitted to the core team by email or FTP.



Figure 3: Polygon and point geospatial elements

Data is verified and enhanced by the core team with open source geospatial software tools. uDig is the desktop GIS software and PostGIS/PostgreSQL is the database management system.

## 4.2 Web Repository and Portal

The web-based repository, including the database (with geospatial extensions), web servers, search and presentation components are all based on open source software.

**4.2.1 Database:** The object-relational database management system is PostgreSQL. It is a powerful award-winning enterprise class system that is SQL compliant and has extensions for spatial capability based on the PostGIS standard. PostgreSQL supports a comprehensive list of data types and has native programming interfaces for Perl, Python, Ruby and other programming languages (PostgreSQL Global Development Group, 2008).

The PostGIS extension provides support for geographic objects in PostgreSQL. It supports Open GIS Consortium (OGC) standards for geometries and functions. It makes possible complex queries and sophisticated spatial operations on these objects. It can import and export most geographic data types (Ramsey, 2007).

PostgreSQL with PostGIS is used in many academic, government and commercial organizations.

**4.2.2 Web Servers:** The web servers are run on the Apache Software Foundation's HTTP Server.

The web servers run applications implemented in Python and Ruby-on-Rails. These languages enable development of rich, complex and interactive applications.

**4.2.3 Participation Applications:** The site is open to all. Participation in forums and contribution of material requires registration.

Web page content has many components. These files and resources are managed using the open source content management system Drupal.

Drupal supports user directories, forums and email newsletters. (Drupal, 2008)

## 5. RICH INTERNET APPLICATIONS

Recent developments in web applications enable rich interfaces for searching for and presenting information. Rich Internet applications (RIA) run in a web browser and have the features and functionality of desktop applications (Loosley, 2006). Rich Internet Applications do not require software installation.

These RIA are used for graphical interface for geographic and timeline-based searches of heritage sites and data. Interactive applications are especially suitable for searching for sites or specific content artefacts.

The web portal has several useful approaches for performing searches through the documentation repository.

### 5.1 Multidimensional search

The text-based, multidimensional search approach uses the parameter criteria shown in Table 1.

Search criterion parameters	Core data index	Example values
Name of building	1.1	Lal Qila
Site Region	2.1	India
Urban locality	2.1	Delhi
Historic location name		Shajahanabad
Architectural style		Mughal
Historic period	4.1	Mughal
Calendar period	4.3, 4.4	1648-1657
Category	3.1	Military, Religious
Function	3.2	Fort, Mosque
Architectural Element		Arch, Column, Muqarna
Content Artefact		3D model, Geospatial coordinates, Images

Table 1: The parameters for search

Many of the parameters are in alignment with the Core Data Index defined by the Council of Europe. The corresponding section of the index is identified in the table.

Searches are performed using one or multiple of these parameters.

### 5.2 Geographic search

Queries are performed using graphical, map-based geographic searches. Map interfaces show cartographic elements or satellite imagery, with zoom and pan capabilities, current or historical locations, countries, kingdoms, sovereignties.



Figure 4: Sample search result using bounding rectangle

Bounding rectangles can be defined within the maps to explicitly define a location search boundary as in Figure 4.



Figure 5: Sample search result using administrative boundary

Alternatively, administrative boundaries for national, provincial or municipal areas may be used for defining the location search, as shown in Figure 5.

### 5.3 Timeline search

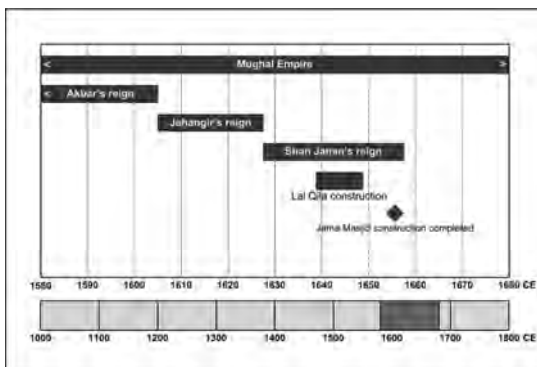


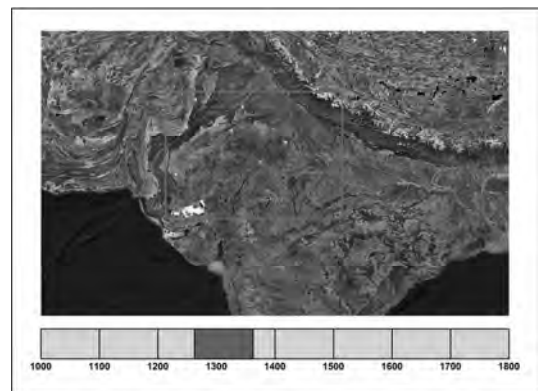
Figure 6: Timeline search interface

Graphical timelines are set on scales that can be selected from calendar types, such as Common Era, Hindu, Hebrew or Islamic/Hijri. Moving the time cursor (red slider over the grey

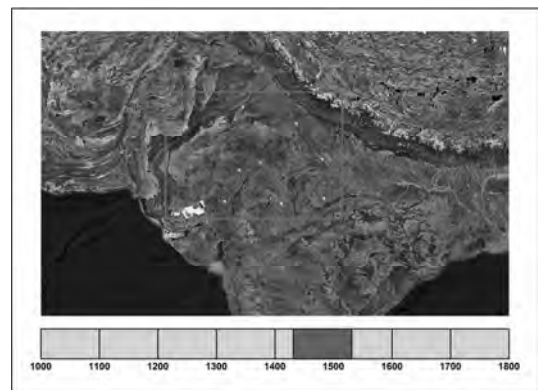
time scale at bottom of figure) along the timeline shows appropriate time-oriented entities such as historic period, reign, and date site was built, as shown in Figure 6. Clicking on a timeline gives more information about the entity.

### 5.4 Combined geographic and timeline search

This search employs both maps and timelines to perform graphical interactive queries in time and geographic dimensions. Figures 7a and 7b show two instances of the interface at different periods in the timeline.



a)



b)

Figure 7: a) and b) show the combined geographic and timeline search interface at two periods—the red slider on the timeline indicates the period

### 5.5 Content management and presentation

Photographic images, architectural elements, drawings, 3D model files, PDF files with embedded 3D models are managed with the help of the Drupal content management system. It has modules for image gallery display, document management and discussion forums.

Acrobat Reader for PDF enables users to view embedded 3D models. Applications based on Google Maps API facilitate viewing of geographic data.

## 6. PROCESS CONSIDERATIONS

An efficient data collection process is essential for documenting hundreds, even thousands of sites a year.



Using local resources is effective and efficient. Recruitment and training over network links has been demonstrated to work successfully.

Internet technologies such as email, wikis, and voice-over-IP provide channels for communicating and interacting with geographically distributed group of researchers. However, this does not always work smoothly. There can be misunderstandings due to lack of direct contact or due to cultural and work-style differences.

The project team that guides the field researcher must be aware of these subtleties and work to mitigate them. Approaches to reduce problems and misunderstandings include redundant communications, such as, following up with an email message after a phone conversation or following training sessions with individual email messages to check that the training was effective.

There is significant turnover in field researchers. The first assignment for a new researcher involves only a few hours' work. If they are able to complete it satisfactorily, more work is assigned; if not they are not given any further work..

As the network of field researchers grows, and the online discussion forum knowledgebase increases, it will become easier for the researchers to learn from each others' experience. New researchers will be able post questions in the discussion groups and get them answered by more experienced researchers.

## 7. COST FACTORS

There are three major items that contribute to the cost of the system.

**Software and system development:** This is mostly an upfront cost for portal implementation and software development of rich internet applications. This work will be performed in countries where costs can be kept low. There is significant software development experience with open source tools around the world.

**Field researchers:** Individual field researchers work for a short time on this project. Researchers are paid on an hourly basis, consistent with the level of work and pay scales in their region. Substantial data can be collected in 10 to 40 hours of field work. As interest in the portal grows, it is expected that some field researchers will participate *pro bono*.

**Core project team:** Initial size of the core project team is two people. The team performs the project management for software development, coordination of field research, checking, editing and enhancement data for the portal. This is a lean team but the intent is to keep cost low and record as many sites as possible.

## 8. CONCLUSIONS

The pace of documentation of built heritage in developing countries is at a low level. Many sites have been damaged or destroyed. Many more are vulnerable. Documentation using high definition techniques is expensive and time-consuming and thus precludes mass documentation initiatives.

Online social and collaborative networks, which have developed in the last decade, have demonstrated that collaboration between geographically dispersed groups to produce useful tangible results is feasible. People in these groups do not know each other except through the online network; and due to their interest and the means of communications provided by the Internet, are able to deliver astonishing results. Networks grow exponentially when they obtain a critical mass of participation. Wikipedia and OpenStreetMap are leading examples.

Local and international interest in built heritage sites is substantial. It is viable to draw on this interest to build research networks for low-cost documentation.

Open source software and rich internet applications enable development of data collection tools and portal interfaces that are sophisticated, interactive and informative. Expertise for the development of Internet applications based on open source tools is distributed all over the world. Skilled and low-cost development teams are obtainable.

Social networks, open source tools, collaboration between geographically distributed contributors combine to provide low-cost and timely options to large-scale built heritage documentation.

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# **Digital Libraries**



## PLANNING OF A METRIC HISTORICAL AND DOCUMENTAL ARCHIVE FOR THE REALIZATION OF A CITY'S CULTURAL PORTAL

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**KEY WORDS:** Cultural Heritage, G.I.S., 3D Modelling, Historical Cartography, Photogrammetry, Laser scanning

### ABSTRACT:

In the Ionian Sea, in the center of the homonym gulf the city of Taranto rises, on a tongue of land between two seas. The one outside is the Great Sea, delimited by the Islands “Cheradi”, connected with the one inside, the “Mar Piccolo”, through two channels, the natural one, to west of the island, on which the historical city rises, and the artificial one, to east in direction of Lecce. The historical core rises on an island constituted by a portion of land, at present, isolated from dry land, but originally to it joined. Today the modern city is developed on the two portions of dry land just behind the island. Main objective of the performed job has been to safeguard the historical knowledge and the preservation of the documentation of the city of Taranto. To recall the historical evolution of the area were necessary the tools of investigation, proper of the historian, integrated to those of analysis and of cartographic representation. In this logic, has been collected a whole set of graphic and iconographic documents preserved in the Record Office in Taranto and in the City Historical archives. The process has been realized through the knowledge of the historical-topographical development of areas that since the Neolithic epoch have marked the evolution of the city. The diachronic rebuilding of the landscape and the ancient context has been carried out through different and coordinated activity such as, archaeological recognitions and cartographic production of sites, photogrammetric surveys and restitutions, 3D productions obtained by terrestrial laser scanners and the analysis of historical and archival documentation, particularly of historical cartographies, epigraphs and relevant iconographies. The georeferentiation of the historical cartographies in Taranto has been realized at first through a process of inverse dating, achieving a cartographic base of reference, beginning from the actual situation. The determination of the GCPs has taken place by a topographical GPS survey. The overlap of the cartographic data has been done by a Geographic Information System constituted by a collection of basic data for the description of the physical, anthropical and historical components of the inspected territory and from the elaboration of specific thematic maps that highlight the main transformations both to urban scale that to territorial scale. Subsequently inside the system all the results, related to the different adopted techniques, have been introduced. Viewed the remarkable proportion of data and information of technical and cultural disposition, it has risen necessity to implement a metric cartographic database (DBMS), which had the abilities to integrate data and documents deriving from different sources and with metric and representative characteristics not homogeneous. The realization of an integrated system allows different actors (public administrations, researchers and professional men) to have an open source platform that integrates information giving back an objective reconstruction and in conformity with their typical demands.

## 1. INTRODUCTION

### 1.1 Historical introduction

The urban area of Taranto since the most remote origins and without solution of continuity, has suffered processes of transformation and readjustments that have articulated the most salient stages of its civil and cultural history. In every epoch the history of Taranto is articulated by the most incisive role playing coastal areas and the harbour docks of the two seas, the best of the whole coast of southern Italy, in activity since prehistoric times. Beginning from the II millennium a.C. it has beginning the history of Taranto. To the Neolithic period date back the settlement of “Porto Perrone” (inhabited area of the Bronze Age, attested by proofs) and that of “Scoglio del Tonno” (the emporion, testified by the discovery of a notable amount of archaeological finds related to Aegean Age). Since the XIII-XI sec. a.C., thanks to the presence of coastal harbour systems, connections were developed with the centers of the Aegean world (Lippolis E., 1994). At first through the Mycenaean trades, then through the process of Greek colonization by Sparta (770 a.C.), in the area of the “Città Vecchia” there is the birth of a settlement that is the polis (city-state), Greek for culture, institutions and language. Beginning from the Greek colonization that has made of Taranto the

capital of “Magna Grecia” (Stazio A., 1970), are followed, during the centuries, Romans, Byzantines, Norman Swabians, Aragonese. These colonizations left significant signs recoverable, today, thanks to the most famous existing architecture (Greek temple, Aragonese castle, Romanesque churches, etc.). It is, nevertheless, beginning from the second half of the eighteenth century that, in the corps of the city, the most significant building transformations happen, transforming Taranto in a port city essentially devoted to the fishing. The expansionistic politics of Bonaparte, proposes and highlights the exceptional strategic role of the port and the roadstead of Taranto and, in this period, started the most important military constructions among which the arsenal, the construction of the channel and the revolving bridge, the classification of “Mar Piccolo” as port of first class for shelter and defense (Speziale G.C., 1930) and the substitution of the old “Ponte di Pietra” with a new revolving bridge to facilitate the small cabotage (Figure 1). In the postwar period, the crash of the great naval and mechanical industry produces crisis, unemployment, unfruitful and disjointed attempts of reconversion often frustrated by the insufficient efficiency of the great network infrastructures (harbor, railroad, roads) and from the substantial absence of a project of development for the city (Cazzato V. et al, 1978). Taranto in 1959 welcomes the Italsider, a new great

“key industry”, with the same uncritical determination with which had received the military arsenal in nineteenth century.



Figure 1: Revolving bridge

The city is run over by an intervention that promises welfare for the local entrepreneurial class. Taranto, at least till to the first Sixty years, will live, even though contradictorily, its economic miracle. In the first Eighty years, the Italsider, harshly hit by the crisis of the iron metallurgy, is not able to give anymore certainty to his work force neither to sustain the induced activity and the general growth of the city. In the most recent years, the renewed attention to the role that the territory in its complex performs in the harmonic development of the Taranto area is confirmed by the amount of projects and financings that concern fundamental objectives of ecological salvage: protection, recycling and availability of the environmental, landscape and monumental emergencies, depollution of “Mar Grande”, up to the restoration of the mussel farming, exploitation and safeguard of the coastal areas and the irrigated and woody patrimony of the province.

### 1.2 Introduction to this work

Taranto has suffered in the years a loss of knowledge of its historicity, although being among the cities more invested by historical alternations. This is caused by a negligence of the local governments preceded to such functions and to an indifference of the population. In the last years the importance of the historical recovery of the cities is also openly felt by Taranto. Nevertheless years of carelessness have made difficult the recovery of any source of historical reliability, documents and studies of the city. In this context has decidedly been necessary and notably difficult to start the recovery of the historical, archaeological, architectural patrimony of the city. The wide wealth of cultural heritage of Taranto requires exploitation contextualized in a cognitive historical path. The objective preset in our work has been that to provide a fit tool of research, knowledge, safeguard and diffusion of the city cultural patrimony. To carry out it, a logical series of processes has been started that, beginning from the historical investigation of the city (through iconographies, documents and cartographies) until to the archaeological and architectural recognitions supported by photogrammetric surveys, restitutions and 3D productions (about which will be described following), has provided an informative base of easy use such as a portal of culture.

## 2. GIS IMPLEMENTATION

### 2.1 Analysis of city cartographies and iconographies.

A diachronic analysis of Taranto has been performed with the purpose to understand the actual territory order and, at the same time, to estimate its dynamic evolution. Have been taken in examination a set of graphic documents, constituted by the list of views and representations of the city, preserved in libraries, Record Office in Taranto, City Historical Archives, Monuments and Fine Arts Office, covering a temporal arc from the Neolithic age to nowadays (Figure 2). Not all the analyzed cartographies are characterized by a precise historical dating and therefore, in order to define a chronological order, is made necessary a careful and long analysis of the spatial-formal configuration of every single image allowing to organize it in a period preceding or following to those of which the dating was known.

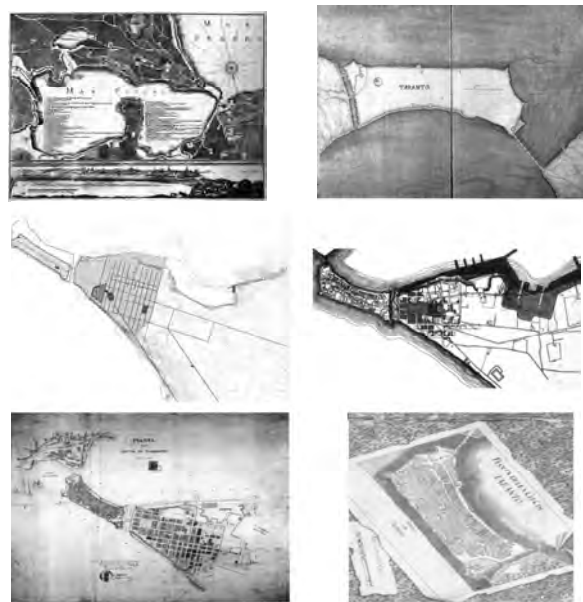


Figure 2: Historical cartographies

### 2.2 Historical cartographies georeferentiation and GIS implementation

Each cartography and historical map has been scanned using instruments with elevated performances that nevertheless cannot make to put aside from the well known errors related to transformation such as those of alignment and of position.

In the phase of georeferentiation, it is necessary, moreover, to consider some intrinsic deformations, caused by the problems of preservation of the papery support and by the different systems of projection.

This process has been performed through the software ENVI proceeding at first to the georeferentiation of the most recent image (Hi-Re color ortho-photo) and going through, for alternation, to those chronologically less recent. For the correction of this image is used the methodology “registration image to map”, using a set of coordinates of points acquired on the image and a relative set of ground control points (GCPs), acquired through GPS survey (Figure 3). To this end, before, two campaigns of measures GPS are carried out, in rapid-static

modality, with 32 points, acquisition times on every vertex of 15 minutes and sampling interval of 5 second.



Figure 3: Georeferentiation “image to map” process

The procedure of registration in ENVI is constituted by two phases: the procedure of warping (deformation), fitting image to the geographical coordinates with the GCPs, performed with the polynomial method of 2° and that of resampling (a digital value has been attributed to each pixels of the image), for this procedure is chosen the method Nearest Neighbor. Geo-referred the first image, are individualized some points in common between this and the immediately preceding image, proceeding so backwards until to the most ancient representation with a process of georeferentiation “registration image to image”. With this procedure the coordinates of the pixels of the image already geo-referred (basic image) correspond to those of the pixels of the image to be geo-referred (warp image). In this case for the phase of warping is used the method RST (Rotation, Scaling, Translation) or polynomial of 1° (Capra A., Costantino D., Todaro S., 2003). For each image have been, therefore, located some points in correspondence of buildings and recurrent structures, such as, for example, the Aragonese Castle and other constructions in proximity of the area of Taranto “Città Vecchia” and partly in the industrial area, in proximity of the “Porta Napoli” bridge.

Remarkable problems are been found in the selection and individualization of these points, seen the presence of wide natural surfaces and not yet build, that have not allowed always a uniform and homogeneous distribution on the area examined. The greatest error originated from a not perfect interpretation of the points image, due both to a detailed information's absence and to the morphological changes suffered by the buildings, considered instead as invariant in following cartographies. The analysis of residual (RMS Error) has underlined, above all, some problems for those areas in which are had to make some conditioned choices. Nevertheless, also in these cases, the accuracy of the process of georeferentiation results acceptable.

All the geo-referred cartographies have been imported in ArcView, software useful to the management of a relational

cartographic database and that, moreover, allows an elaboration of the networks data with server-client structure. For each cartography have been vectorized, through points, lines and polygons, the characteristic elements and has been created a shapefile for an analysis of the territorial extension and the building development (Figure 4).

It is proceeded, therefore, to the attribution of a numerical coding for the vectorial objects to make possible the direct connection between the tables of the attributes (automatically generated for each polygon) and those of the Access Database.



Figure 4: Visualization and vectorization of the cartographic maps in GIS

### 3. 3D MODELLING

#### 3.1 Surveys planning

Have been performed, in the years, surveys and three-dimensional metric reconstructions of numerous characteristic sites of the city of Taranto among which: the columns of the Temple of Poseidone (Dell'Aglio A., De Vitis S., 1994), various archaeological Neolithic sites, the Church of St. Domenico, the Cathedral of St. Cataldo, the Bridge of St. Eligio, the Archiepiscopal Seminary portal, the urban area of “Porta Napoli”.

For each site have been adopted different approaches and techniques of survey and extracted the elements necessary for the knowledge and representation of Cultural Heritage. In the planning of surveys, therefore, it is defined the fittest technique to represent the monument. Nevertheless, seen the multiplicity and the variety of the surveyed objects, more than the adoption of a single technique is had to implement and to study the opportune integration of topographical techniques and the combination of the results.

The whole fund of data and information acquired has made necessary, finally, the georeferentiation of each element constituent the single survey, in the all representations set. For the greatest part of the sites has also been adopted the laser scanning technique that represents a method for the digitalization and the modelling of objects and portions of territory with any shape and dimension. The digitalization takes place in discrete mode through the measurement of the position of an elevated number of points (Costantino D., Angelini M. G., Capra A., 2004).



### 3.2 Surveys and elaborations

The bridge of “Porta Napoli” has a strategic role of hasp between the ancient inhabited area and the nineteenth-century expansion on the mainland (Figure 5). The actual configuration is only the last of a series of structures that are followed by the beginning of nineteenth century to today (Costantino D., Rossi G., Angelini M. G., Leserri M., 2006).



Figure 5: “Porta Napoli” bridge

The survey of the bridge has been performed through integration of laser scanner technique and topographical support. The point clouds, results of the single acquisitions, are been assembled for reconstituting the complete object (Figure 6).

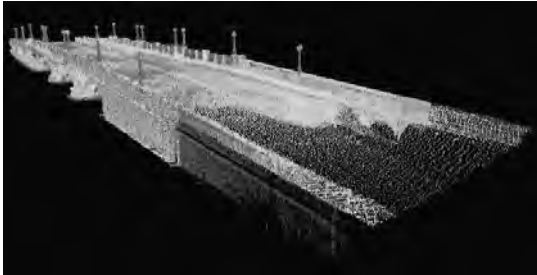


Figure 6: Point Clouds representation

The most significant constructive and decorative elements have been individualized (Figure 7) and for these is proceeded to the realization of the three-dimensional model (El-Hakim S. F., 2001).



Figure 7: Surface 3D Modelling

The temple of Poseidone has dating in archaic age, exactly at the end of the first twenty-five years period of the VI sec. a.C.; instead, any remarkable data hare emerged for the reconstruction planimetric of the building (Phillip F, 1976). Following frequenting of the area have been documented, despite the deep tamperings suffered by the site, from levels of

frequenting and from structures with different function, connected with the religious edifices of this area (silos, cisterns and crypt-ossuary).

Through the same techniques is gained the modelling of the two surviving columns of the Temple of Poseidone (Capra A., Costantino D., Maggi R., 2003). Has been performed the photogrammetric restitution and a realistic reproduction started through the process of texture mapping with the integration of the laser data with that photogrammetric one (Figure 8).

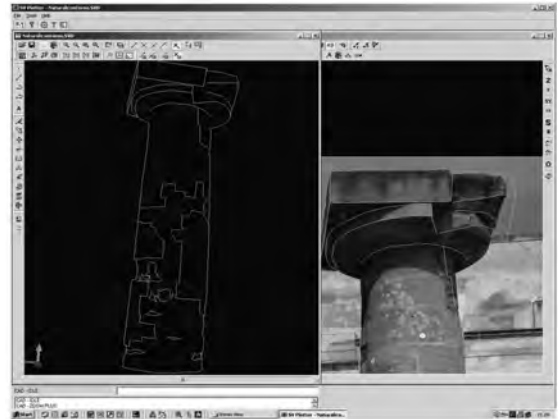


Figure 8: 3D Modelling with texture map and particular

The ancient church of S. Domenico rises where in Byzantine epoch there was a monastic installation named S. Pietro Imperiale, whose original nucleus seems it preexisted to the IX century. The church was reconstructed in 1302 (when some Dominicans in Angevin age installed there). The inside of the church has a Cross Latin plant, with a unique aisle, once embellished from a valuable wooden ceiling, and with a short transept on which a dome is risen resting on pointed arcs, while the square apse has cross vaults (Blandamura G., 1923). The survey has been performed through laser scanner technique planning a series of scans taken by different points of view necessary to get a total coverage of the elements constituent the church. Plans and characteristic sections of the cathedral are been extracted (Figure 9).

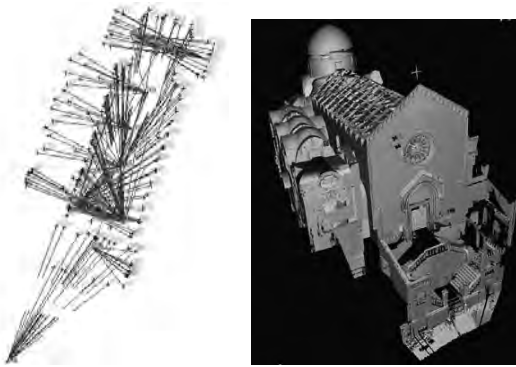


Figure 9: Topographical support and modeling

The Cathedral of St. Cataldo was built by Byzantines in the second half the X century. On the old Byzantine installation, in the last years of the XI century, the actual cathedral was built with basilican plant. Nevertheless the old construction was not substituted entirely; the longitudinal arm, enlarged and depressed, incorporated the central aisle and the deep Byzantine apse was unaltered (Figure 10).



Figure 10: Image and laser scanner survey of "Cupolone San Cataldo"

For the old building of the Archiepiscopal Seminary in Taranto (XVI century), overlooking the Great Sea, in front of the islands of S. Pietro and S. Paolo, the works of restoration of the whole building had been started and particularly the interventions of architectural restoration of the principal portal.



Figure 11: Archiepiscopal Seminary Portal before restoration

During the interventions of restoration, inside the complex, different architectural finds have been recovered, displaced helter-skelter among which was necessary to recognize those constituent the frieze, that, nevertheless, presented a bad state of preservation (Figure 11).

With the help of the photogrammetric restitutions (El-Hakim, S., 2006), of the models obtained through the elaboration of the laser data and, with the cognitive historian support, is simulated the reconstruction of the frieze and of the mouldings in their wholeness (Costantino D., Capra A., Angelini M. G., 2005). This activity, further providing an indisputable cognitive data, assisted the interventions of restoration (Figure 12).

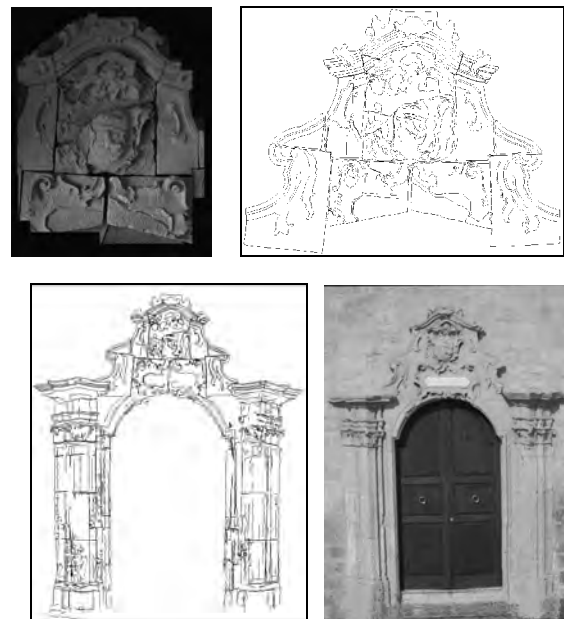


Figure 12: Simulation and subsequent intervention of restoration

The possibility to apply techniques of integrated survey on archaeological sites is revealed particularly useful in the cases in which the high density of discovered information and the numerous elements to be represented don't allow to accomplish,

with an only methodology, the metric applications of the archaeologists and all those people that operate in the cultural historical circle (El-Hakim, S.F., Beraldin, J.A., Picard, M., Godin, G., 2004). At this end, on a Neolithic archaeological site, situated in Taranto and named "Masseria Cesaria", methodologies of integrated survey are been conducted through traditional topographical technique, photogrammetric one, GPS, laser scanner and elaboration of remote sensing images (Figure 13- 14).

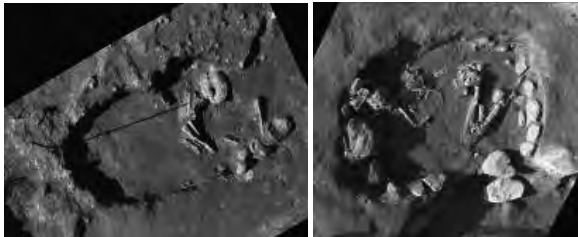


Figure 13: Ortho-photo



Figure 14: 3D laser model and sections

Describing summarily the events and the transformations of the city, it has been possible to represent and model these. (Figure 15).



Figure 15: Interpretation of iconographic documentation

Have been symbolized in simplified three-dimensional vision (Figure 16), through the help of historical cartographies, of iconographies and of surveyed data, the most historical important characteristic changes of the city of Taranto (Costantino D., Rossi G., Angelini M. G., Leserri M., 2006).

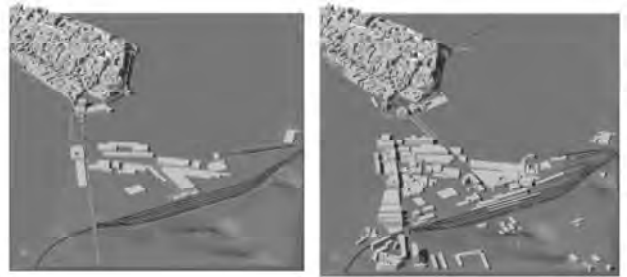


Figure16: Diachronic analysis

#### 4. PORTAL OF CULTURE

##### 4.1 Metric Database and GIS

Necessity to organize information of technical-cultural disposition has emphasized need to plan and to implement a specific interdisciplinary database, in which make suitable information to represent the link between the cultural patrimony and the economic development of the city, accessible to users of different typologies. The first phase of the work has been the organization of the data and the planning of the archive for the following population of the database, through the historical documentations, photographic, etc, with the georeferentiated historical cartographies and organized in the different historical periods taken in examination. To make the procedure of date-entry and query simple and intuitive, opportune masks of visualization and/or input are been created. The principal mask of the DBMS is structured so that to allow the access all the files and all the information inherent the project (Figure 17).



Figure 17: Principal database mask

From the section Historical Periods it is possible to have access to the files of each epoch organized for further epochs. For each historical Age the database is structured in 2 levels: a first level with a brief description associated to a synoptic table of the distribution of the principals sites and installations of this epoch; a second level with the cartography (Figure 18), the photographic references, the 3D reconstructions of the principal architectural elements, the bibliographical references, etc, inherent each historical moment of the period in examination.



Figure 18: Mask of historic period VII-III mill. A.C.



Figure 18: Mask of “Magno Greco” period

To allow an easy management of the data, characterized by a complex articulation, results right a database with relational architecture type. In this way is possible the transit from a more general knowledge of the historical period to a more detailed (buildings, monuments, archaeological sites, etc). The updating of the database, with technical material such as photogrammetric surveys, laser scanning surveys, plans, georeferenced cartographies, etc. has allowed the accomplishment of a metric and iconographic archive of simple management and use and has allowed also the implementation of the database with the data from the laser scanner surveys of the Church of St. Domenico, of the “Ponte di Pietra” and the Doric Columns (Figure 19).



Figure 19: Laser scanner survey of Doric columns

With the databases, is realized, the GIS, customized according to the specific needs. The informative system has been realized through the building of two modules: one of input, visualization and graphic-spatial query, managed through the ArcGIS software (Figure 20); the other, connected to the first one

through the SQL link, for the management of the alphanumeric data (database), realized in ACCESS (DBMS).



Figure 20: GIS/ACCESS SQL link

The realization of this system integrated with that GIS allows the different actors (technicians interested to the geo-referred cartographic apparatus or historians employed to the knowledge or to the enrichment of the portal) to have an open source platform that integrates information, giving back an objective reconstruction and respondent to their own demands.

The integration with information coming from external users accessing the system, will be collected in a dedicated open source file named "suggestions". These will subsequently be analyzed and compared with the existing data and then will be used for the portal integration and enrichment.

### 5. CONCLUSIONS

The realization of a portal of culture for the city of Taranto has allowed to exploit its applicability in the urban-architectural and cultural field.

The introduction of metric and cartographic material, has been finalized to the use by the employees that can access the portal to consult, to integrate and to provide hints and proposals of improvement.

The portal is not only moreover for specific use but it must also be seen as possibility of diffusion and cultural exchange to different levels (schools, cultural centers, museums, etc.).

The possibility to have in every time a file so detailed and more and more integrable allows moreover to preserve and to safeguard the cultural patrimony of the city.

The portal of culture will be available on the web as soon as data will be checked and tested by local corporation and authority and soon enjoyable through a link in the Geomatica laboratory web page of the Faculty of Engineering in Taranto - Polytechnic of Bari.

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## WEB ARCHIVE SWITZERLAND COLLECTING AND ARCHIVING WEBSITES AT THE SWISS NATIONAL LIBRARY

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**KEY WORDS:** Cultural heritage, Long-term preservation, Web archiving, National libraries, Switzerland

### ABSTRACT:

Web Archive Switzerland is a project undertaken in collaboration with the Swiss cantonal libraries as part of the e-Helvetica project at the Swiss National Library. The mission of the Swiss National Library is to collect and archive all Swiss publications, both printed and electronic. The objective of the e-Helvetica project is to fulfill this mission for electronic publications. The goal of the Web Archive Switzerland project is to set up a collection of selected regional and cultural Swiss websites and to preserve them in the Digital Archive of the Swiss National Library. In collaboration with several cantonal libraries we have designed and tested a shared workflow for the collection, cataloguing, archiving and dissemination of the websites. Widely used applications, exchange methods, standards as well as programs are used to harvest the websites and to ingest them into the Digital Archive (Heritrix, webform), to describe the websites in the catalogue (MARC, AACR2, CONSER) and to identify the websites within the Digital Archive (URN on the basis of NBN). This paper gives some general information on the e-Helvetica project and how the Digital Archive is being built. The approach chosen for the collection, cataloguing and dissemination of the Swiss websites is highlighted as well as the creation of a social infrastructure together with the Swiss cantonal libraries and other partners.

### 1. INTRODUCTION

It is the task of national libraries to preserve the intellectual and cultural heritage of their countries. Nowadays much of this heritage is expressed in electronic form and many national libraries have started projects to collect and archive electronic publications. As a result standards and best practices have emerged that new initiatives are able to draw upon.

The Digital Archive of the Swiss National Library draws on the Open Archival Information System that describes a technical and organizational infrastructure for preserving data and making it available to a defined user group. The federal governance approach in Switzerland requires the creation also of a social infrastructure to support the archiving.

At the Swiss National Library the various activities and projects that are needed to build these capabilities have been brought together under the umbrella of the e-Helvetica project. As part of e-Helvetica, Web Archive Switzerland is a good example of the approach being taken to address the issues that emerge in the preservation of Swiss cultural heritage for the future.

### 2. THE SWISS NATIONAL LIBRARY AND THE E-HELVETICA PROJECT

The Swiss National Library was founded in 1895. It is the main source worldwide for written material on Switzerland and the Swiss. The Swiss National Library has a legal mandate (Federal Act on the Swiss National Library of December 18, 1992) to collect, catalogue, preserve and make available printed information as well as information stored on media other than print that has a bearing on Switzerland - this is called "Helvetica". The term Helvetica is used to denote the entire literary production of the country stored on all forms of

information media (handwritten manuscripts, printed, digitized, in pictorial form or as sound documents), all works published abroad with a bearing on Switzerland, its population, its past, present and future works (including translations) by Swiss authors. The collection of the Swiss National Library consists of over 3.8 million items with an average growth of 50,000 items per year.

The Swiss National Library is not subject to legal deposit legislation for either printed or electronic publications. However since 1915 there has been an agreement on the gratis supply of Swiss publications, signed by the Swiss National Library and the Swiss Booksellers and Publishers Association. This agreement was renewed in 1961. A specific agreement for electronic publications does not yet exist.

The 1992 Federal Act does not specify the type of media, simply that the information must be related to all that is Switzerland and the Swiss. With the rise in importance of the Internet since 1993, the Swiss National Library began addressing the question of how in the future electronic publications could be stored on a long-term basis and thus preserved for subsequent consultation. National libraries have the task to work actively against the loss of intellectual and cultural heritage. Electronic media represents more and more an important part of this heritage. As a result, national libraries are facing new, additional and far-reaching tasks.

Since 2001 the e-Helvetica project of the Swiss National Library has taken on these tasks.

The goal of e-Helvetica is to establish the foundations for the collection, cataloguing, archiving and dissemination of electronic Helvetica, both offline (electronic publications on data carriers such as CD-ROMs or floppy disks) and online

(electronic publications published on the web without any data carrier such as e-journals and websites).

The project is divided into two separate initiatives. The Organization initiative deals with the librarianship aspects of the e-Helvetica collection – that is, determining the collection’s contents, their cataloguing and their dissemination. Archiving covers the IT aspects of the e-Helvetica collection, namely the setting up of the technological foundations and the IT applications for preparing and storing the collection.

The project is being developed by specialists in library science as well as IT experts. There are nine project staff equivalent to a total of 3.8 FTE’s.

The e-Helvetica project is on schedule to be completed and operational by the end of 2010.

## 2.1 Establishing the electronic collection

The Swiss National Library has decided to build a selective rather than a comprehensive collection of electronic publications. The Swiss National Library does not have the resources nor the legal mandate to collect the entire .ch domain. Accordingly, the decision was made to begin with selective coverage but to guarantee long-term preservation for this data. Offline publications such as CD-ROMs and floppy disks will be collected to the fullest extent possible. Online publications such as e-journals and websites will be collected selectively but in as broadly representative a range as possible.

Four pilot projects have been chosen for the implementation phase of the e-Helvetica project. Together these cover a broad range of content types from various producers of electronic publications.

**2.1.1 Online theses:** The “e-Diss.ch” project (Signori, 2007) focuses on collecting online theses from Swiss universities. The collection is being developed through the coordinated efforts of the Swiss National Library and the Swiss university libraries, with the support of the Conference of University Libraries in Switzerland.

**2.1.2 Online commercial publications:** Project “POP” collects online commercial publications belonging to the Basel-based Karger-Verlag publishing house. The collection comprises mainly online journals, monographs and book series. It is being built in collaboration with the publisher.

**2.1.3 Web resources:** “Web Archive Switzerland” deals with the collection of relevant regional and cultural websites (grey online literature). The collection is being developed together with the Swiss cantonal libraries, who are responsible for the selection of the publications to be collected.

**2.1.4 Online governmental publications:** “e-Publications Confederation” covers the collection of official online publications of the Federal Administration. Partners are the Federal Offices. This project involves the Swiss Federal Archive.

## 2.2 The processing and storage of the electronic Helvetica collection

The Digital Archive of the Swiss National Library is being built according to the directives of the Open Archival Information

System (OAIS). Adopted as ISO 14721, this reference model (see Figure 1) describes an archive as an organization where people and systems work together on the problem of preserving information data and making it available to a defined user group. The model gives a detailed description of how producer-issued electronic information should be integrated into an archiving system, what preparatory steps must be undertaken for long-term archiving, and how information stored in the archive can be accessed (Consultative Committee for Space Data Systems, 2002).

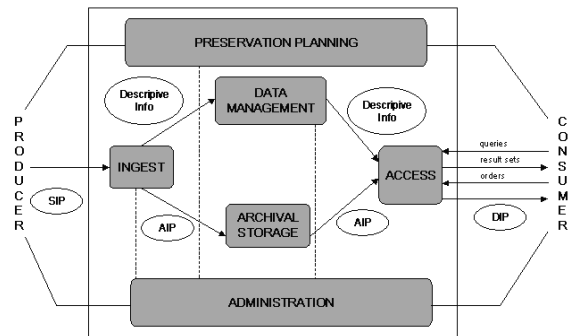


Figure 1: OAIS reference model

In e-Helvetica each OAIS process is tackled as a separate IT project.

**2.2.1 Archival Storage:** The archival storage process has been designed to create synergies within the Federal Administration in collaboration with the Swiss Federal Archive. The storage system was put out to WTO (World Trade Organization) tender; Tape Libraries from ADIC (Advanced Digital Information Corporation) and Hierarchical Storage Management (HSM) from StorNext were chosen. The data is stored on LTO-2 (Linear Tape Open) and AIT-3 (Advanced Intelligent Tape) tapes running in Neuchâtel and Berne with redundancy across the two systems. In its current configuration the storage system can store up to 30 TB data and is scalable to 300 TB. This configuration will be refreshed until the end of this year. The AIT-3 tapes are due to be replaced and the long-term storage system needs to be better integrated into the existing IT architecture of the Federal Administration. The new National Library system will consist of a redundant NAS-system (Network Attached Storage) from Network Appliance. It will have a capacity of 9 TB each and will be housed at two different physical locations in Bern.

**2.2.2 Ingest:** The company Elca was chosen in another WTO tender to set up an Ingest system for the Swiss National Library. The Ingest system manages the automated delivery of the online publications (together with the metadata) to the Library and processes them until the digital objects are finally stored in the Tape Libraries. Ingest integrates the existing tools for the collection of the online publications and is flexible enough to meet future developments. It has been operational since 2007.

**2.2.3 Data Management:** Part of the Data Management process was defined alongside Ingest. The Swiss National Library’s metadata format is based on the standard developed by the Library of Congress: METS (Metadata Encoding & Transmission Standard, <http://www.loc.gov/standards/mets/>). MARCxml (<http://www.loc.gov/marc/>) is used for the

bibliographic metadata. For technical and administrative metadata, the Preservation Metadata format of the National Library of New Zealand PRESMET (National Library of New Zealand, 2003) is used. Another part of the Data Management process will be defined alongside Access. Especially when dealing with Digital Rights Management.

**2.2.4 Access:** The process for ensuring access to the stored online publications is still at the planning phase, scheduled for implementation in 2010. The library catalogue Helveticat of the Swiss National Library serves today as the entrance point for all media collected at the Library. It is therefore likely that access to the Digital Archive will be through Helveticat. A special interface and a cache system will operate between the library catalogue and the Archive.

### 3. WEB ARCHIVE SWITZERLAND

The goal of the Web Archive Switzerland project is to establish an archive for relevant regional and cultural Swiss websites at the Swiss National Library with automated processes for handling them. In addition, websites of events in or related to Switzerland are also included (e.g., Parliamentary elections 2007, European football championship 2008 in Switzerland and Austria). The ultimate aim is to give users permanent access to the archived websites through any portal.

The technical and organizational infrastructure needed for Web Archive Switzerland is being developed within e-Helvetica. Accordingly, the technical platform to process websites is built on the basis of the OAIS reference model and uses standards as well as widely used applications as much as possible (e.g., Heritrix, METS, MARCxml, URN).

The building of relations with the Swiss cantonal libraries and other stakeholders has been critical to the success of this project. It has enabled resources and knowledge to be shared among the libraries and institutions in Switzerland and abroad. The Swiss National Library is member of the International Internet Preservation Consortium (IIPC, <http://www.netpreserve.org/>). Most important however is the creation of a social infrastructure that ensures that standards and processes are followed and that the web archiving becomes an integral part of the day-to-day library workflow.

The key to building the social infrastructure is the integration of the stakeholders into the project from a very early stage - making them a part of the project as it develops. A number of techniques are used to help build stakeholder commitment. A network of contact people at the Swiss cantonal libraries - technical and strategical - was established and they are kept updated on progress regularly through letters, e-mails, workshops and conferences. These people also helped to test the webform and other ingestion processes. Partnerships were set up with other projects, institutions and networks in Switzerland and abroad. No single technique has proven successful by itself; rather it is the combination that is effective. It is worth noting that considerable time and effort is required to establish and maintain the social infrastructure. For e-Helvetica so far this has been 20-30% of the total project effort.

#### 3.1 Partners

Switzerland is a federal state made up of individual states called cantons. There are 20 cantons and 6 demi-cantons in

Switzerland. Each canton and demi-canton has its own cantonal library which each has the task to collect and preserve the cultural heritage of their canton. For this reason, it was decided to work together to build a web archive for Switzerland.

11 of the cantonal libraries (Basel-City, Fribourg, Geneva, Jura, Neuchâtel, Solothurn, St. Gall, Uri, Vaud, Valais and Zug) have been partners since the very beginning of the Web Archive Switzerland project in 2005. Guidelines for selecting and cataloguing Swiss websites were established together, as well as the design and testing of the shared workflow and the Ingest process. Web Archive Switzerland became fully operational on the Spring of 2008 for these 11 cantonal libraries. A permanent working group consisting of representatives of 4 cantonal libraries and of the Swiss National Library guarantees the continuation and optimization of Web Archive Switzerland.

The remaining 15 cantonal libraries and some other interested institutions have just started to learn about Web Archive Switzerland in 2008 through workshops. This will help them to decide if they wish to join Web Archive Switzerland on an operational level in 2009.

#### 3.2 Workflow

A shared workflow has been set up (see Figure 2). The different colours on each side show the areas of responsibility for each party. All the tasks in the light grey area on the left are carried out by the cantonal libraries, the tasks in the dark grey area on the right are carried out by the Swiss National Library.

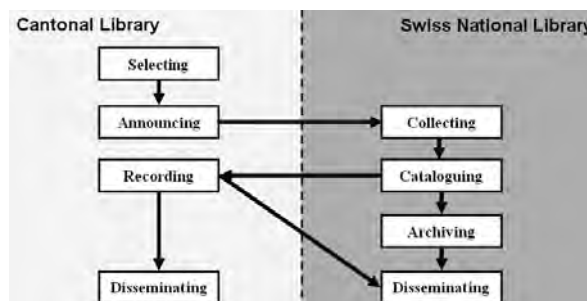


Figure 2: Shared workflow

**3.2.1 Selecting:** The cantonal libraries are responsible for selecting the websites to be included in the Digital Archive of the Swiss National Library. They are the best placed in their canton to know what is important for preservation and what not. Selection criteria have been established together (Signori, 2008a). To be selected for preservation, a significant proportion of a website must be related to Switzerland and its cantons, or be on a subject of historical, social, political, cultural, religious, scientific or economic significance and relevance to Switzerland and its cantons and be written by a Swiss author. Furthermore the website must be publicly available via the internet. For technical reasons websites may be excluded from the collection even if they meet the selection criteria (e.g., databases).

**3.2.2 Announcing:** The cantonal libraries announce the selected websites to the Swiss National Library by completing an interactive webform. The webform is based on Dublin Core Element Set and on MARCxml. The rules how to fill out the form, thus how to catalogue the websites, have been established together and are retrievable online (Signori, 2008b). The



completed webform is sent to the Swiss National Library by e-mail as an XML attachment. The XML files containing the metadata are directly processed into the Ingest system of e-Helvetica.

**3.2.3 Collecting:** The rights for archiving and accessing the websites must be checked before the Swiss National Library “physically” collects the announced websites. In Switzerland there is no legal deposit law at a national level. We are obliged therefore to ask permission of the rights owners for each website that we would like to collect. In an operational environment this is a considerable organizational burden. A study will be carried out in 2008 to analyse the legal situation in Switzerland on this topic and to find feasible solutions. In the meantime we simply inform the rights owners that we are going to harvest their websites and invite them to opt out if they are unwilling to participate. To date there have been no serious objections. Once the rights owners have been informed the harvesting process is started. Ingest uses the open-Source Heritrix web crawler (<http://crawler.archive.org/>) to pick up the websites as digital objects from the internet using the links read from the metadata delivered by the cantonal libraries through the webform. Static websites are harvested only once. Dynamic websites are harvested at pre-defined intervals. The digital objects are returned to Ingest as WARC files. The WARC (Web ARChive) format specifies a method combining multiple digital resources into an aggregate archival file together with related information. The WARC format is a revision of the ARC format that has traditionally been used to store web crawls as sequences of content blocks harvested from the World Wide Web. The motivation to revise the ARC format arose from the discussions and experiences of IIPC, whose members include the Internet Archive and the national libraries of various countries – among them also the Swiss National Library. Quality checks are carried out at different stages of the Ingest process. The digital objects are checked for viruses, authenticity and completeness. The data formats are checked using JHOVE (JSTOR/Harvard Object Validation Environment, <http://hul.harvard.edu/jhove/index.html>) and there is a control mechanism to guard against multiple delivery. Some quality checks must still be carried out manually, for instance checking existing documents and checking if graphics have been harvested correctly. Reliable quality control can only be achieved through the use of a tool that analyses the collected websites and shows possible errors. Such a tool is planned to be developed within IIPC. For each website a URN (Uniform Resource Name) is generated automatically on the basis of National Bibliography Numbers ([urn:nbn](http://www.persistent-identifier.de/?lang=en)) for the unique identification in the Digital Archive of e-Helvetica. The URN resolving service of the German National Library (<http://www.persistent-identifier.de/?lang=en>) is used for this purpose. It records each URN with its corresponding URL's and is responsible for the correct resolution of the URN to these URL's.

**3.2.4 Cataloguing / Recording:** The bibliographic metadata from the XML attachment is transformed from MARCxml into MARC21 and sent to the library catalogue Helveticat automatically creating a catalogue record. We defined a minimal cataloguing level using the Anglo-American Cataloguing Rules (AACR2, <http://www.aacr2.org/>) for static websites and the CONSER Cataloguing Manual (<http://www.itsmarc.com/crs/man11573.htm>) for dynamic websites. For each announced website a single record is created. Some information (e.g., authorities) is added or checked later directly in the catalogue Helveticat. The cantonal libraries can

add their records to their local library catalogues afterwards if they wish.

**3.2.5 Archiving:** A final control step automatically checks that all information gathered during the ingestion process has been recorded in the metadata. The completed metadata package is stored in Data Management (see Figure 1). The archival information package that contains the website as well as its metadata is stored in the Digital Archive in the form of a tar ball (Locher, 2008a).

**3.2.6 Disseminating:** The Access process within e-Helvetica is not yet implemented and therefore Web Archive Switzerland is not yet publicly accessible. It is envisioned that access to the digital publications will be through the Swiss National Library catalogue Helveticat. The URN will resolve first to the URL of the original publication on the internet. In the event that a publication is not or no longer available on the internet, the URN will resolve to the URL of the copy stored at the Swiss National Library. Since the Digital Archive itself will never be directly accessible to the user, a publication will be delivered from a cache. Copies of highly requested items will be stored on the Cache system and will be delivered in real time from there. Other items will be requested from the Digital Archive as needed and made available to the user via the Cache. Access to the websites will also be possible through the cantonal libraries' local catalogues, the library networks' catalogues and through a common interface for Web Archive Switzerland. Furthermore tests of other Access tools such as the Wayback Machine from Internet Archive are planned. If suitable these will be used in the Access-solution (Locher, 2008b).

### 3.3 Event-harvesting “Parliamentary elections 2007”: facts and figures

Parliamentary elections take place in Switzerland every four years. The most recent elections for the National Assembly of Switzerland were on October 21, 2007. Most of the cantons also elected their representatives for the upper chamber on the same day.

The National Assembly of Switzerland is one of the two chambers of the Swiss Federal Assembly. It consists of 200 members each elected for four years by voters in the cantons. Each canton has the right to at least one seat; the remaining seats are allocated in proportion to each canton's population. The upper chamber of the Swiss Federal Assembly is the federal body of Switzerland. Each canton sends two representatives to it and each demi-canton sends one, making a total of 46 members.

For the Swiss National Library it was a good opportunity to carry out an event-harvesting for the first time and to gain some experience. The Library worked together with the Parliamentary Services and the European Archive on this event. The Parliamentary Services provide assistance for the Federal Assembly to fulfil its allotted tasks. They enable the members of parliament to concentrate on their legislative works and keep them fully informed, as well as helping them to address the challenges posed by a constantly changing society. Parliamentary Services selected 15 websites of the major Swiss Parties to be included in the Digital Archive of the Swiss National Library.

The Swiss National Library informed the Parties by letter that we were going to harvest their websites. There were no objections.

The harvesting was carried out by the European Archive and took place twice, once before and once after the elections. 827,000 files were collected on the first crawl, corresponding to a volume of 41,5 GB data. 1,086,184 files were collected on the second crawl, corresponding to a volume of 54,5 GB data.

The quality check was carried out in two steps. The European Archive carried out their quality control first, eliminating errors. Further quality control was then carried out at the Swiss National Library using a web interface of the European Archive. The control at the Swiss National Library was very time consuming: around 24 minutes per website. The major errors found were: single graphics were missing (external logos), the layout was changed occasionally (special characters), some functions did not work (pull-downs, search, agendas) and some documents were missing.

The Swiss National Library received the collected websites on harddisk from the European Archive and ingested them into the Digital Archive.

The main lesson learned during this event harvesting was that quality control plays a very important role in web archiving. When carried out manually it is time consuming and requires specially trained staff. Moreover, a clear definition of quality is required and decisions made on what quality criteria should apply. These topics will be discussed in IIPC. It is hoped that a automated tool will soon be available for more reliable and less burdensome quality control.

#### 4. CONCLUSION

National libraries are charged with preserving the intellectual and cultural heritage of their countries. Electronic media, and especially the web, represent an increasingly important part of this heritage. Hence, archiving the web has become a task for National Libraries. The Swiss National Library has undertaken efforts to guarantee long-term access to that part of the internet that concerns Switzerland and the Swiss.

Web archiving is not as simple as it may seem. We believe for instance that it can never be considered complete. Even if we decided to harvest the entire .ch domain, the websites can be updated weekly, daily or hourly and we can never capture all instances of a website.

Our goal is to create an archive that can be used by future generations to gain an insight into how we use the internet today and what contents are important today. Our approach is to take snapshots of the web, showing how it was at a particular point in time, how it was used, and what part it played in our society. This is Web Archive Switzerland.

The availability of information by itself does not ensure the visibility of that information. It must be findable and retrievable. The project Web Archive Switzerland sets standards that guarantee visibility across Switzerland and that guarantee supply of the information into the future.

Web Archive Switzerland is also of great value as a project to the e-Helvetica team at the Swiss National Library. It provides a real test of the technical infrastructure of the Digital Archive

systems. Just as important however it allows the team to gain valuable experience in establishing the social infrastructure that will ensure the lasting success of digital archiving in Switzerland.

We have learned a number of important lessons during the project so far:

Chief amongst these has been the establishment and management of the social infrastructure. The cantonal libraries are very different from each other in many ways. It was essential to find common elements that were important to all the libraries, which then formed the basis for collaboration: for instance, the shared workflow, collection criteria, cataloguing rules, and the standardized webform procedures. These were all defined collaboratively with the cantonal libraries, making them part of the process. This co-operation was greatly appreciated and resulted in strong motivation to participate. We organize a number of formal and informal networking opportunities to stimulate collaboration between partners. Managing the social infrastructure is a key part of the project, taking up to a third of the total time spent on the project.

The pilots have shown that the cantonal libraries need training in the selection and announcing of the websites. Workshops have been organized in 2007 and 2008 and are very likely to be repeated yearly. The training helps the cantonal libraries to carry out their tasks more efficiently.

Obtaining permission to harvest a web resource has proved extremely time-consuming; it has become a significant part of the workflow. Maintaining good relationships with the website owners is essential.

We are beginning to realize that we will probably need to set limits on the size and/or format of websites so that we can harvest more efficiently. This is currently the subject of much discussion and we have yet to decide on our approach. An alternative might be to manually pre-analyse the websites.

We have found that quality control is especially important when harvesting selectively. At the moment we do not know of a tool that could do this automatically so all quality control is manual. We find that this is time consuming and requires specially trained staff.

Last but not least we have learned a great deal from other National Libraries and organizations involved in web archiving and long-term preservation. The exchange of ideas, opinions and approaches is of benefit to all in this emerging field.

For further information please check the website of e-Helvetica at <http://www.nb.admin.ch/e-helvetica>.

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# BIODIVERSITY HERITAGE LIBRARY: BUILDING A DIGITAL OPEN ACCESS LIBRARY FOR BIODIVERSITY LITERATURE

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**KEY WORDS:** Biodiversity Heritage Library, BHL, scanning, zoology, botany, digitisation, portal

## ABSTRACT:

Ten major biodiversity libraries have collaborated in digitising biodiversity literature in an open access manner via the Biodiversity Heritage Library (BHL) project. Participating in the BHL project are Natural History Museum, London, Royal Botanic Gardens, Kew, Smithsonian Institution, Harvard University, Field Museum, Chicago, New York Botanical Garden, American Museum of Natural History, Missouri Botanical Garden and Woods Hole Oceanographic Institution.

The BHL project's aim is to make biodiversity knowledge available to anybody who has an interest in it – and on an open access, Creative Commons basis. Optical Character Recognition (OCR) techniques will be used to extract the relevant information from digitised objects. Taxonomic intelligence tools are used to overcome the issue of changing names, names using local languages and plurality of names for the same object (synonyms). A research scientist, student or member of the public, who has access to the Internet anywhere in the world, will be able to search for specific information in all of the literature relevant to biodiversity and transparently link the documentation to taxonomic, geographic, biographic, or other relevant databases.

The BHL is a global partnership because no single library holds the complete corpus of legacy literature. The partners' collections will represent a comprehensive assemblage of this literature. The BHL, as a community-based partnership, will provide a trusted grouping to negotiate with copyright owners. Within two years, the BHL will have made approximately 15 million digitised pages of literature available. The BHL Portal is available at [www.biodiversitylibrary.org](http://www.biodiversitylibrary.org).

## 1. INTRODUCTION

In the spring of 2005, representatives of ten major natural history museum libraries, botanical libraries, and research institutions joined in a collaborative effort to develop strategies to digitize the legacy biodiversity literature in an open access manner. From this partnership grew the Biodiversity Heritage Library (BHL) project.

The partners envision that a research scientist or student who has access to the Internet, located anywhere in the world, will be able to search for specific information in all of the literature relevant to biodiversity and transparently link the documentation to relevant taxonomic, geographic, or other useful databases. Such a tool would erase much of the expensive, labour-intensive work of library research and speed the production of research results many times over.

### The Partnership

The participating institutions are:

- American Museum of Natural History (New York, USA)
- The Field Museum (Chicago, USA)
- Harvard University: Botany Libraries & Ernst Mayr Library of the Museum of Comparative Zoology (Cambridge, USA)
- Marine Biological Laboratory/Woods Hole Oceanographic Institution (Woods Hole, USA)
- Missouri Botanical Garden (St. Louis, USA)
- Natural History Museum (London, UK)
- New York Botanical Garden (New York, USA)
- Royal Botanic Gardens (Kew, UK)
- Smithsonian Institution (Washington, USA)

The BHL members have formed an Institutional Council with elected officers and have signed agreements committing them to the project. Other participants are being sought and tentative agreements have been reached with the Chinese Academy of Sciences and the Atlas of living Australia. A consortium of 24 European institutions is also being set up under the title BHL-Europe.

### 1.2 Why digitize this literature?

The BHL libraries collectively hold a substantial part of the world's published knowledge on biological diversity. Yet, this wealth of knowledge is available only to those few who can gain direct access to these collections. This body of biodiversity knowledge is thus effectively withheld from wider use for a broad range of applications, including research, education, taxonomic study, biodiversity conservation, protected area management, disease control, and maintenance of diverse ecosystems services. Much of this published literature is rare or has limited global distribution and is available in only a few libraries. From a scholarly perspective, these collections are of exceptional value because the domain of systematic biology depends -- more than any other science -- upon historic literature. To positively identify a rare specimen, a working biologist may have to consult a 100 year-old text because that was the last time the organism was found, recorded, and described. The "cited half-life" of natural history literature is longer than that of any other scientific domain and the "decay-rate" of this literature is much slower than in other fields (cf. biotechnology). Mass digitization projects at large research libraries lacking the discipline-specific focus of these partner institutions may fail to capture significant elements of this biodiversity legacy.

The BHL will be of value to scientists but also for many other potential users. Citizen scientists who lack affiliation with major research institutions will now be able to search, read, download, and print collections that were previously unavailable to them. Artists can use the detailed illustration in many taxonomic works as motifs or design concepts in their work, whether on canvas, paper, or digital. Educators guiding students in how to do biological research will have a wealth of examples to incorporate into lesson plans and assignments. We already have examples of artists and educators exploiting the small amounts digitized already by BHL libraries.

The greatest diversity of the biota exists in tropical and developing countries, yet the literature documenting that biodiversity is primarily held in a few North American and

European libraries. Digitizing this literature and making it available freely on the Internet will be an act of significant intellectual repatriation. Currently, teachers and scientists from developing countries who need to read this literature must visit, expensive urban centers such as London, New York, or Paris, using their very limited funds. All BHL libraries report visitors queuing at their copying machines to bring needed material back to their home countries. As an example, Dr. Ravi Joshi, Chief Scientist at the Philippine Rice Research Institute, recently wrote to the Smithsonian Institution, “*Currently we at PhilRice have a global taxonomic project on the rice black bug (Scotinophara spp.). Please we need to refer to the ancient scientific literature on this insect. At the National Library in Philippines, we do not have access to all of the literature listed in the attachment (attached file). Please can you help us on how to get access to them from your library.*”

The BHL partnership is essential because, while natural history museum and botanical garden libraries have collected biodiversity materials comprehensively, including many specialized and rare materials, no single library holds the complete corpus of legacy literature. The partners’ collections represent a uniquely comprehensive assemblage of this literature. The BHL plans to provide approximately 100 million digitized pages of literature to support multiple bioinformatics initiatives and research. For the first time in history, the core of our natural history museum and botanical garden libraries will be available to a truly global audience.

### 1.2 Key Benefits and Outcomes

The BHL partners identified the following potential benefits and outcomes from the project:

- BHL expects that the Web availability of the majority of the biodiversity literature will have a long-term impact on the way that taxonomic science is done. The ability to bring together all the literature on a given taxon or group at an individual’s desktop will increase efficiency and speed up the process of taxonomic revision. Large paper collections of individual articles may become a thing of the past.
- The BHL will lead to an acceleration of the taxonomic process in both developed and developing countries. This supports the wider objectives of the EOL and enables the greater integration of taxonomic effort globally.
- Full-text searching and taxonomic intelligence will ‘unearth’ inaccessible information from older material. This will allow new analysis and data mining by bringing together material from different institutions to provide a new synthesis.
- The BHL will expose the biodiversity literature to other biological science disciplines – ecology, forestry, land planning, environmental assessment, etc. - and a broad range of other potential users in medicine, history, the arts, and the social sciences.
- The BHL will also provide improved access for non-taxonomists to original descriptions and identifications. Such links could provide powerful new tools to medical researchers or environmental and ecological monitoring organizations, where precise species identification is critical for their work.
- Full access to the published literature will effectively

repatriate biodiversity information back to the original country containing described organisms. In many cases in the developing world, local taxonomists and para-taxonomists will have access to the literature on their local biodiversity.

- Access to the BHL content will support the curricula of training new taxonomists in developing countries. This can help mitigate the “Taxonomic Crisis” [www.actionbioscience.org/biodiversity/page.html](http://www.actionbioscience.org/biodiversity/page.html)
- The number of out-of-town visitors that need to visit our library collections should reduce significantly. This ‘saving’ will persist and should help to boost local capacity.
- The BHL will provide a low cost “not-for-profit” mechanism for small learned and professional societies to make the backfiles of their journals digitally available.

## 2. METHODOLOGY

BHL members have already scanned their institution’s own scientific publications to contribute to the BHL. Members will scan other volumes from their collections that are not covered by copyright, or for which permissions have been obtained, using the Internet Archive, a non-profit partner, to quickly add large segments of literature to the corpus. Ongoing negotiations with commercial publishers and learned society publishers are promising: newer literature may be made available with permissions. The BHL will be perceived as a community-based partnership that demonstrates respect for copyright owners and will be able to negotiate from this trusted position. Small society publishers need help scanning and storing their publications, and if we provide this service, some are pleased to have their content accessible through the BHL Portal – 49 publishers have already agreed to make their material available through the BHL.

### 2.1 Scanning

The BHL selected the Internet Archive (IA), an organization with demonstrated technical capabilities in mass scanning and long-term digital content management, to scan the bulk of the literature through their scanning centres. A scanning centre consists of multiple, high-speed, state-of-the-art digital book scanners, with staff for two shifts daily, each able to handle large numbers of volumes. The IA will perform imaging, optical character recognition (OCR), text creation, association of standard metadata (derived from MARC records provided from the libraries’ catalogs) with the digitized files, file arrangement, security, and delivery of the completed scans in conformance with agreed project standards. Article-level access to journals will be provided. In many cases BHL libraries will partner with other local libraries to support Internet Archive scanning centres in Washington, New York, Boston, London, and elsewhere.

### 2.2 BHL Portal with Taxonomic Intelligence

The digitized literature will be served to users from the Biodiversity Heritage Library Portal hosted by the Missouri Botanical Garden. The BHL Portal will create an innovative, freely accessible, research environment that will provide Web Services to support research in life sciences and conservation. The BHL Portal will use informatics tools to identify strengths and overlap across the participating institutions’ libraries and to help solve the problems associated with the naming of organisms. The scanned materials will be referenced by persistent globally unique identifiers (GUIDs) at various structural levels, e.g. title, volume, article, etc. so that they can

be integrated into existing bibliographic and taxonomic citation databases, like Tropicos, NameBank, and Zoological Record. The binomial biological names of organisms annotate content about species in biodiversity literature. However, the use of names for information retrieval is impeded because names are neither stable nor consistent. One organism may have more than one name. This prevents simple automated indexing services from bringing together complementary data. Moreover, about 1% of names change each year, such that the many-names-for-one-organism (synonyms) problem accumulate with time and is particularly severe with heritage literature. Visitors to traditional library scanning projects who know organisms by their colloquial (common) names may be unable to find content unless they know the names used in the source documents. These issues might reduce the utility of the millions of pages of primary biodiversity information to be generated by the BHL without the added tools intended in the BHL Portal. The uBio team from the Marine Biological Laboratory/Woods Hole Oceanographic Institution (MBLWHOI) library has assembled an array of taxonomically ‘intelligent’ services designed to overcome these problems, and we will apply them to the BHL content. Building on existing tools and services developed by uBio to index organism names (NameBank, which contains approximately 10 million name strings) and their associated hierarchies (ClassificationBank, which contains over 80 classifications), taxonomic intelligence will be integrated into the documents as soon as they are OCREd using an established named entity recognition tool, TaxonFinder. The integration of taxonomic intelligence will enable linkages to other relevant indexed content in the Encyclopedia of Life (EOL) and other Web-accessible name-based resources.

### 2.3 Selection of Materials to be Scanned

The BHL involves many separate institutions with different collection strengths. Material selection will be multi-dimensional including thematic areas, date of publication, and quantity of material. BHL Directors have organized a “BHL Collections Working Group,” which will refine and further articulate the thematic areas in 2008. The initial titles to be scanned will either be in the public domain or have copyright permission. In addition to thematic focus provided by the EOL, the BHL will also analyze such major indexes as *Index Kewensis*, Sherbourne’s *Index Animalium*, and Neave’s *Nomenclator Zoologicus*. BHL staff are already in discussions to obtain permissions to mine *Zoological Record* to determine those journals that have been most cited in the literature of species identification and description. This will provide a priority list of journals and monographs. Scanning from a prioritized list created through citation analysis ensures that the BHL contains the most critical works for our audience of scientists and scholars. BHL will also remain flexible enough to take timely advantage of offers from significant learned society journals to digitize back holdings or the needs of specific biodiversity projects.

Our current priorities include:

- The MBL and Harvard MCZ will prioritize marine literature and expect to digitize 70% of the pre-1923 marine literature.
- The Smithsonian will initially prioritize entomological literature and expects to complete 40% of the pre-1923 literature.
- The Missouri Botanical Garden, New York Botanical Gardens, Harvard Botany, and the Royal Botanic Gardens, Kew will prioritize botany and expect to digitize 70% of the pre-1923 literature.

Current committed funding from the John D. and Catherine T. MacArthur Foundation and the Alfred P. Sloan Foundation and funding to be raised from other sources will enable the digitization of approximately 68 million pages of core literature by December 2011. Based on analysis of indexing sources for biodiversity literature, it is estimated that approximately 1,200,000 species were described before 1923 in the extant literature.

### 2.4 Portal Development and Web Services

Users today expect sophisticated presentation and collaborative, interactive Web resources. To make this Web Portal operative, the BHL will program an intelligent, customizable interface into all parts of the repository. The interface will enable users to conduct a search for particular terms in the BHL repository and find pages where these terms occur throughout the entire collection of digitized literature. Users will be able to obtain a bibliography of the literature containing the keyword(s) or view the individual scanned pages (or the indexed text if they prefer). In addition to the Portal’s internal search capabilities and outward external links, it will provide a mechanism to accept queries from external databases, libraries, or individual Web users, returning appropriate images or bibliographic references. In scanning these historic titles, BHL will produce electronic resources that can be incorporated into publishing schemes and referenced alongside current research. It is important that these resources are available to harvesting engines, aggregators and other applications via service layers. To ensure that these resources remain globally accessible and usable by the widest possible audience, BHL will assign persistent identifiers at varying levels of granularity using methods that accommodate both graphical user interfaces (GUIs) and application program interfaces (APIs). Examples of one type of persistent identifier, Digital Object Identifiers (DOIs), developed by the International DOI Foundation, are resolvable identifiers that separate intellectual content from physical location. DOIs are widely used in modern scholarly and professional publications, and will facilitate assignment of persistent, resolvable identifiers to historic literature.

Testing of the system will be critical to determine whether the BHL Portal reaches its intended audience and will include internal review by the BHL partners and reviews by other scientists and IT professionals. The BHL will undertake testing for all components and subsequent modification and retesting as needed throughout the project. The BHL Portal will undergo intensive testing and evaluation, including post-deployment surveys and online comment/suggestions options.

The BHL Portal will communicate with the IA and other service providers assisting the project using Web Services, a mechanism by which data can be shared among disparate data sets using standard protocols and XML. Building Web Services on top of the BHL Portal will allow us to “publish” our materials so that other communities can enquire and interact with the BHL data. For example, a conservation organization might be interested in finding literature on a given species, but requires the literature to be displayed in its own application. The organization’s application can address BHL’s Web Services and determine what digitized literature is available for the scientific name in question. The results will provide in-links to the BHL digitized literature from the organization’s existing application. In this way, Web Services will meet the specific needs of this usage, while continuing to make the raw data available to others.

## 2.5 Digital Sustainability

Digital curation is a critical part of making the BHL a sustainable project that will ensure sustained, persistent access to the BHL content for centuries using the best available technology and administrative structures for preservation of digital files. A plan for extending collaboration from the

original core group of institutions to include many other natural history and botanical libraries is being pursued actively. The metadata, image files, digital derivatives, and text files generated during this project will create a significant resource that will require ongoing stewardship. The BHL Institutional Council will be developing a plan for archival storage and appropriate migration of data. The plan may involve multiple dark archives and the participation of primary publishers of content (such as commercial publishers and society publishers), as well as content aggregators such as OCLC. Working with their host institutions and major stakeholders, BHL Directors will develop a plan for long-term administrative/corporate structures to ensure that the BHL digital assets remain freely and openly available to users in the long-term.

## 3. PROGRESS SO FAR: BHL DEVELOPMENTS TO JUNE 2008

The BHL project is making rapid progress and already has a number of major achievements to its credit

- BHL now manages more than 6.0 million pages from over 15,000 digitized scientific texts. To stay updated on new titles visit [www.biodiversitylibrary.org/Recent.aspx](http://www.biodiversitylibrary.org/Recent.aspx).
- Browse by Names: users can view the most frequently found names from our taxonomic name finding tools, which have found more than 16.7 million name occurrences, and view a bibliography at [www.biodiversitylibrary.org/browse/names](http://www.biodiversitylibrary.org/browse/names)
- BHL Name Services are XML-based Web Services that can be invoked via SOAP or HTTP GET/POST requests to query and harvest our index of names, generated through incorporation of TaxonFinder.
- Integration with EOL enables BHL Name Services to link EOL Species Pages to BHL bibliographies e.g. for Great white shark [www.eol.org/taxa/17143484?category\\_id=9](http://www.eol.org/taxa/17143484?category_id=9)
- Filtering by Contributing Library: when users select "Browse By:" functions, they can filter results using the "For:" dropdown to view, for example, Authors from the New York Botanical Garden, or a Map of titles scanned by Smithsonian Institution.
- The BHL produces stable URLs for book-marking and persistent linkage to the main parts of the content.
- Link to Developer Tools: we have documented our Name Services, URLs, and all kinds of technical information at [www.biodiversitylibrary.org/Tools.aspx](http://www.biodiversitylibrary.org/Tools.aspx)
- Feedback tracking: users can submit feedback or comments on records using the link at the top of the Portal page.
- Filter by language: users may filter results by the language in which items are published. For example, Titles published in English, or Authors with works published in German.
- Advanced Search: users user may search on any combination of search categories (Titles, Authors, Names, or Subjects), instead of just one or all of the categories.

- The Gordon and Betty Moore Foundation made an award of \$1 million to the Missouri Botanical Garden to deliver robust digital asset management functionality using the Fedora Commons platform. The release of the BHL Portal v.2 into production for public use, incorporating the Fedora Commons platform, will take place in 2009.
- Working with partners in across Europe, the Berlin Museum fur Naturkunde has submitting a funding request to the European Commission in the neighbourhood of €4 million for the establishment of BHL-Europe. If received, this funding will go for staffing and infrastructure to manage a parallel European initiative. A related proposal will be submitted to the German Government for digitizing approximately 50 million pages. This content will be available through the BHL though it may not be hosted by the BHL.

We expect progress to continue to be rapid and we will be releasing new versions of the software and many more page images over the next few years.

## 4. ACKNOWLEDGEMENTS

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# **Data Acquisition and Remote Sensing in Cultural Heritage II**





# A MULTI-RESOLUTION METHODOLOGY FOR ARCHEOLOGICAL SURVEY: THE POMPEII FORUM

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**KEY WORDS:** 3D modeling, multi-resolution, integration, image matching, laser scanning

## ABSTRACT:

The article reports about a multi-resolution approach developed for the 3D modeling of the entire Roman Forum in Pompei, Italy. The archaeological area, approximately 150 x 80 m, contains more than 350 finds spread all over the forum as well as larger mural structures of previous buildings and temples. The interdisciplinary 3D modeling work consists of a multi-scale image- and range-based digital documentation method developed to fulfill all the surveying and archaeological needs and exploit all the potentialities of the actual 3D modeling techniques. Data's resolution spans from few decimeters down to few millimeters. The employed surveying methodologies have pros and cons which will be addressed and discussed. The preliminary results of the integration of the different 3D data in seamlessly textured 3D model, will be presented.

## 1. INTRODUCTION

The generation of reality-based 3D models of objects and sites is generally performed by means of images or active sensors (like laser scanner or structured light projectors), depending on the surface characteristics, required accuracy, object dimensions and location, project's budget, etc. Active sensors (Blais, 2004) provide directly 3D data and combined with color information, either from the sensor itself or from a digital camera, can capture relatively accurate geometric details. Although still costly, usually bulky, with limited flexibility, not easy to be used everywhere or at every time and affected by surface properties, active sensors have reached a maturity since some years and the range-based modeling pipeline (Bernardini and Rushmeier, 2002) is nowadays quite straightforward although problems generally arise in case of huge data sets.

On the other hand, image-based methods (Remondino and El-Hakim, 2006) require a mathematical formulation (perspective or projective geometry) to transform two-dimensional image measurements into 3D coordinates. Images contain all the useful information to derive geometry and texture for a 3D modeling application. But the reconstruction of detailed, accurate and photo-realistic 3D models from images is still a difficult task, particularly for large and complex sites, or if uncalibrated or widely separated images are used. Besides range- and image-data, surveying information and maps can also be combined for correct geo-referencing and scaling. Although many methodologies and sensors are available, nowadays to achieve a good and realistic 3D model containing the required level of detail, the best approach is still the combination of different modeling techniques. In fact, as a single technique is not yet able to give satisfactory results in all situations, concerning high geometric accuracy, portability, automation, photo-realism and low costs as well as flexibility and efficiency, image and range data are generally combined to fully exploit the intrinsic potentialities of each approach (Guidi et al., 2003; Stumpf et al., 2003; El-Hakim et al., 2004; Guarnieri et al., 2006). Motivated by the increasing requests

and needs of digital documentation of archaeological sites at different scales and resolutions, we report our multi-resolution approach developed for the reality-based 3D modeling of the entire Roman Forum in Pompeii, Italy (figure 1). The archaeological area is approximately 150 x 80 m and contains more than 350 finds spread all over the forum as well as larger structures of previous buildings and temples. In this kind of projects, adequate planning before the field work demands a systematic approach to identify the proper sensor technology and data capture methodology, estimate time for scanning and imaging, define quality parameters, avoid tourists, etc. In the project, the fieldwork had to be completed within a specific time dictated by the availability of equipment and support personnel, allowed access to the site, and project budget. Thus, it was important to assemble the right surveying methodology and an optimum working team on the site to handle all operations effectively.

The modeling methodology was developed to fulfill all the surveying and archaeological needs and exploit all the potentialities of the actual 3D modeling techniques. Indeed the integration of different methodologies is prompted by the increasing requirement for fast and cheap but precise and detailed digital documentation of archaeological sites.

## 2. THE POMPEII FORUM

### 2.1 Brief historical background

The Pompeii Forum was the main square of the ancient city. It was the centre of the political, commercial and religious life. Located in the middle of the so-called "Altstadt", the oldest part of the city placed in the South-Western quadrant of the plan (von Gerkan 1940; Eschebach 1970), it is also the key for the interpretation of the town-planning evolution from the VII century B.C. to the final destruction of Pompeii, due to the eruption of Vesuvius in 79 A.D. The interpretation of the various building phases and the examination of the complex

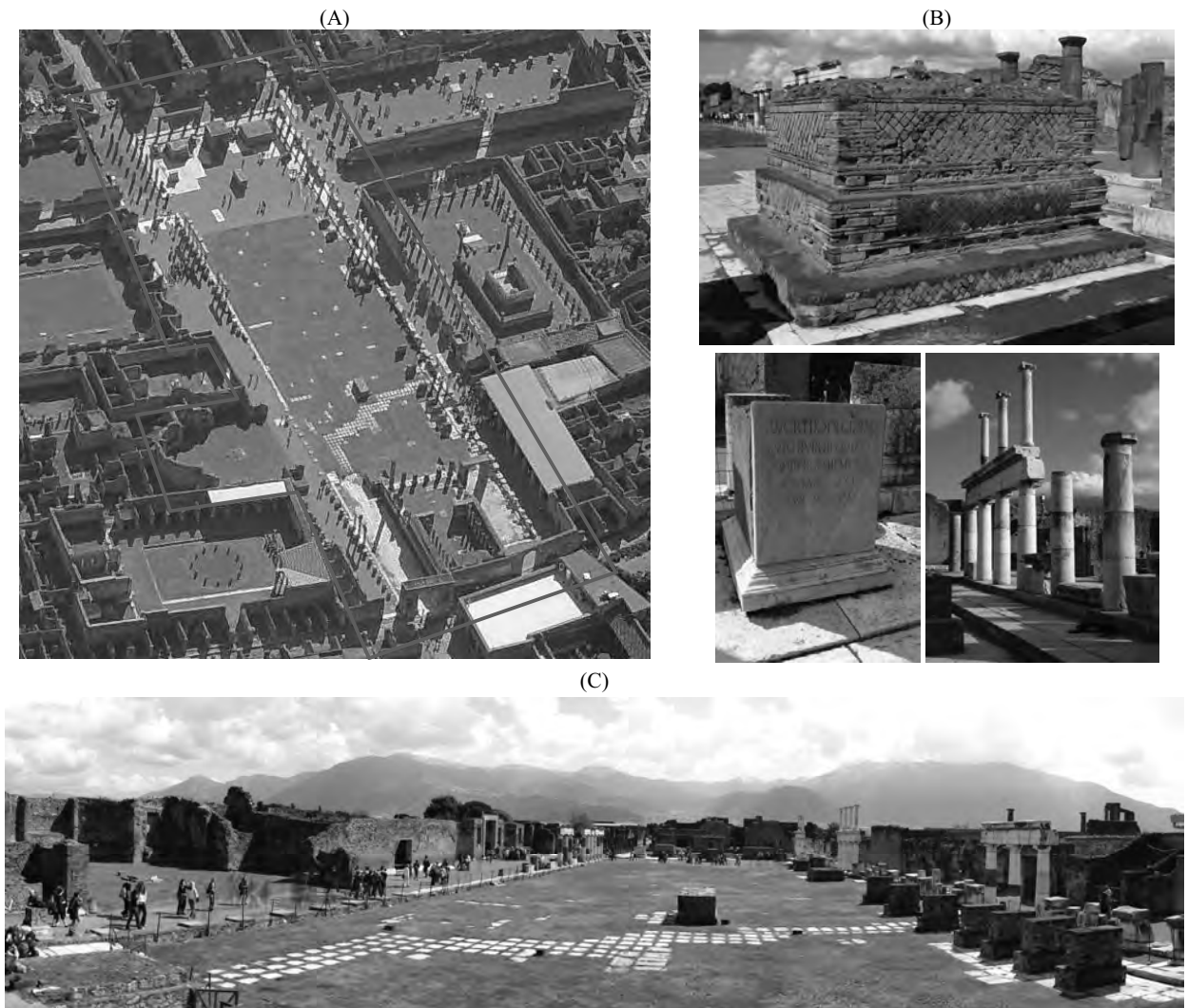


Figure 1: The forum of Pompeii: an oblique aerial view with highlighted the working area (A), some of the finds spread all over the archaeological area (B) and a panoramic view of the Forum, approximately 150 m long and 80 m wide (C).

relationships amongst the walls of the monuments that nowadays are visible in the Forum, are therefore important topics of the archaeological investigation on the urban history of Pompeii.

In its first configuration during the Samnitic period, the Forum had a trapezoidal shape and was oriented following the axis North-West/South-East. This orientation was maintained at least until the second half of the II century B.C., when the Forum was transformed in a rectangular square with a North/South axis, including the Capitolium (Temple of Zeus) in the shorter side, pointing at Mount Vesuvius. The Archaic Forum contained the main square that was paved with pressed volcanic ashes, the Temple of Apollo and some commercial buildings (tabernae) found under the East Porticus. During the late Samnitic period (II century B.C.), the Forum changed completely appearance: the square was paved, the Temple of Apollo was restored and the Macellum was built. Other important buildings were built up during the second half of the century: the Basilica, the Temple of Zeus and the Comitium, together with the so-called Porticus of Popidius along the East and South sides, defining the new orientation of the square. This ensemble of monuments has been interpreted by Dobbins

as a whole and named “Popidian Ensemble” (Dobbins and Ball, 2005). During the Early Imperial Age, in the Roman period, the Forum changed again its aspect and the square was paved with travertine stone, also used for rebuilding the Porch. New monuments were built along the East side of the Forum that was completely transformed with a new complex of buildings dedicated to the Imperial cult: the Sanctuaries of Lares Publici (also called of the Imperial Cult), the Sanctuaries of the Geius of Augustus (or Temple of Vespasianus) and the Eumachia Building. The square was completed with the two monumental Arches placed on both sides of the Capitolium. In 62 A.D. a strong earthquake seriously damaged Pompeii and its monuments were still under restoration in 79 A.D., when the Vesuvius erupted. This chronology needs to be further refined on the basis of further archaeological data. Many researches are currently investigating the history of Pompeii Forum and, through this, the evolution of the entire city. The continuously evolving sensor technologies and data capture methodologies, the new techniques for data acquisition and rendering and the multi-resolution 3D representation can contribute with an important support to the refinement of information and to the growth of the archaeological research.

## 2.2 The 3D modeling project

The survey and 3D modeling of the Pompeii Forum is part of a larger project regulated by two agreements among the company ARCUS, the Archeological Superintendence of Pompeii (SAP) and the Scuola Normale Superiore of Pisa. The first one produced the new SAP Information System, for the management of archaeological information (cataloguing resources and geographic data) related to the vast area around Mount Vesuvius. The second agreement, started in May 2007, consist of (i) the generation of a website for the communication to the broad public of studies and resources on Pompeii's heritage and (ii) the developing of a 3D model of the entire Forum. The modeling work is carried out by the INDACO Department of the Politecnico of Milan in collaboration with other scientific institutes and university departments. The 3D modeling project is also aimed at defining some best practices for data acquisition and rendering of 3D models that will be realized in the future for the Superintendence of Pompeii. The main objective is to establish some core specifications for data acquisition and modeling, in order to guarantee the scientific quality of data and the interoperability of 3D models with the information System. Thus, the working methodology is centered on the strict cooperation between archaeologists and engineers.

## 2.3 Related works

The UNESCO site of Pompeii has been widely surveyed and modeled in the last years. Reality-based reconstructions were already mentioned in the literature on single rooms, houses or monuments (Bitelli et al., 2001; Balzani et al., 2004a; Hori et al., 2007; Iorio et al., 2007). The largest survey was conducted by Balzani et al. (2004b) with a ToF scanner on the entire Forum, although the results were only presented in point cloud form. The Pompeii Project of the Virginia University (USA) aims, with the help of photogrammetry, to provide the first systematic documentation of the architecture and decoration of the forum, to interpret evidence as it pertains to Pompeii's urban history and to make wider contributions to both the history of urbanism and contemporary problems of urban design (Dobbins, Ball, 2005).

Hypothetic reconstructions of the forum, based on the integration of the real geometry of the relics with documents and philological reconstruction date back to the seventeenth century (Weichardt, C., 1898) and have been further developed in recent years with Augmented and Virtual Reality technologies using handmade CAD models (Forte et al., 2001; Papagiannakis et al., 2005) or semi-automatically with procedural models (Mueller et al., 2006).

The work presented here belong to the first category (i.e. reality-based models) and its main goal is the proper integration of technologies for achieving the best tradeoff between accuracy of geometrical and iconographic representation, acquisition and processing time and size of the integrated model, in order to give to the Superintendence of Pompeii an instrument for controlling the complex conservation of the site and to scholars and common public a mean for understanding the stratified Forum structure.

## 3. THE MULTI-RESOLUTION MODELING METHODOLOGY

Multi-resolution data are nowadays the base of different geospatial databases and visualization repositories. Probably the best and most known examples are given by Google Earth or Microsoft Virtual Earth. Data span from hundreds meters resolution (both in geometry and texture) down to few decimeters (only in texture). The user can browse through the low-resolution geospatial information and get, when necessary, high-resolution and detailed imagery, often linked to other 2D/3D information (text, images, city models, etc).

For the 3D archaeological survey of the Forum in Pompeii, a similar approach was selected. A top-bottom methodology (figure 2) was employed, which starts from traditional aerial images and reaches higher resolution geometric details through range data and terrestrial images. For large areas like the Forum, the documentation of both landscape and architectures requires data with very different resolution which must be afterwards carefully registered and integrated to produce seamless and realistic 3D results.

### 3.1 Related works

The multi-resolution approach and the integration of different modeling technologies and methodologies (photogrammetry, active sensors, topographic surveying, etc) are nowadays providing the best modeling results. Indeed each LOD is showing only the necessary information while each technique is used where best suited to exploit its intrinsic modeling advantages. Since the nineties, sensor fusion has been exploited with radars and infrared sensors as a mean for precisely estimate airplane trajectories in the military field (Hall, 1990), but with the end of that decade NRC Canada developed a Data Collection and Registration (DCR) system for integrating a 3D sensor with a set of 2D sensors for registration and texture mapping (El Hakim et al., 1998). Guidi et al. (2002) generated high resolution 3D models of roman mosaic fragments with a pattern projection range camera, oriented them with photogrammetry and integrated these data with TOF laser scanner. In order to give guidelines for the proper application of integrated survey technologies Böehler and Marbs (2004) made an exhaustive comparison between active and passive technologies both in the architectural and archaeological field. Gruen et al. (2006) used a multi-resolution image-based approach to document the entire valley of Bamiyan with its lost Buddha statues and produce an up-to-date GIS of the UNESCO area. Bonora et al. (2006) fused multi-resolution range data to model the Rucellai chapel in Florence. El-Hakim et al. (2008) integrated drawings, images, range data and GPS measures for the detailed modeling of castles and their surrounding landscapes.

## 4. 3D MODELING OF THE FORUM

As demonstrated in the aforementioned literature, the main purpose for adopting an integrated methodology is twofold:

- a) adapt the level of information associated to each artifact contained in the area to the proposed instrument (e.g. conventional photogrammetry for large flat walls, laser scanning for irregular or partially broken wall structures, photogrammetric dense matching for small detailed decorations);

- b) introduce a level of redundancy useful to optimize the model accuracy and/or identify possible metric errors in the model.

#### 4.1 Sensors and data acquisition

For the 3D documentation of the large archaeological area we employed (Table 1):

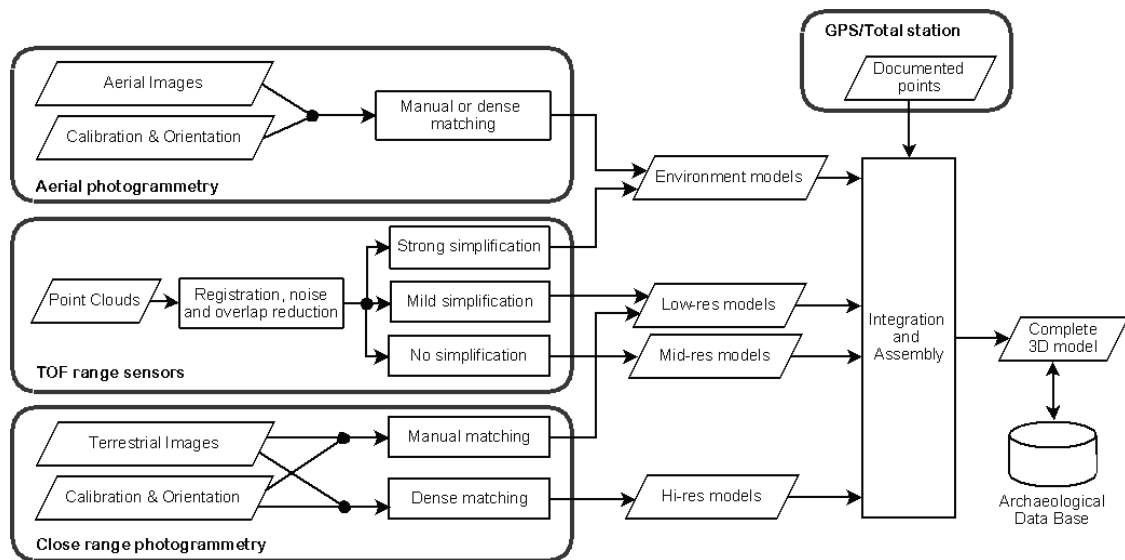


Figure 2: Integration of multi-resolution data for 3D modeling the Pompeii Forum

	Sensors	Use	Quantity	Geometric resolution	Texture resolution
Aerial images	Zeiss RMK A 30/23	DSM of the site at low resolution	3 (scale 1:3500)	25 cm	5 cm
	Pictometry	Texturing	4	-	15 cm
Range sensors	Leica HDS3000	Modeling of entire Forum at middle resolution	21 scans (400 Mil pts)	5-20 mm	-
	Leica HDS6000		45 scans (800 Mil pts)	5-10 mm	-
Terrestrial images	Canon 10D (24 mm lens, 6 Mpixel) Canon 20D (20 mm lens, 8Mpixel) Kodak DCS Pro (50 mm lens, 12 Mpixel)	Modeling of small finds, mural architectural structures, ornaments	3200	0.5-10 mm	0.2-5 mm

Table 1: The employed data for the multi-resolution 3D modeling of the Forum in Pompeii.

1. classical aerial images acquired for a typical mapping project;
2. oblique aerial views for texturing purposes;
3. range-data acquired from the ground with a ToF sensor;
4. terrestrial images to fill gaps, document small finds in higher resolution by means of dense image matching and reconstruct simple structures with less geometric details.

The geometric resolution of the data spans from 25 cm to few mm in geometry and from 15 cm down to few mm in the texture. The use of oblique images (coming from Pictometry technology) was dictated by the fact that the available vertical images dated back to 1987 and the actual situation of the Forum is slightly different.

#### 4.2 Data processing

The available triplet of aerial images (1:3500 image scale) was oriented with a standard photogrammetric bundle block

adjustment, using some control points available from the local cartographic network. For the DSM generation, the ETH multi-photo matcher SAT-PP was employed (Zhang, 2005; Remondino et al., 2008). The matcher derived a dense point cloud of ca 18 millions points (the area is approximately 1 x 0.8 km).

The range data (ca 1.2 billions points) were processed inside Cyclone and Polyworks. The scans alignment (surface-based) and data editing (cleaning, layers generation, sampling and semantic subdivision of different structures) required ca 6 months of work. After cleaning, simplification and overlap reduction, 36 million points were used for the buildings (walls of 14 structures plus a boundary wall) and the DTM, while 64 million points were needed for describing the geometry of 377 archaeological finds all around the forum. A total of 100 MPoints were therefore useful for describing all the geometries in the Forum after 1.2 GPoints of raw data acquired (approx 1:10 ratio).

The terrestrial images (ca 3200) were employed to model all the mural structures, the 377 finds and to derive detailed geometric models of some ornaments by means of dense image matching. Most of the processing, applied to well conserved (flat) structures and to the pieces scattered around the forum, such as pieces of columns, trabeations and pedestals, was achieved with standard close-range photogrammetry software (PhotoModeler), while for detailed surfaces (ornaments, reliefs,

etc) the multi-photo geometrically constrained ETH matcher was used (Zhang, 2005; Remondino et al., 2008).

#### 4.3 Data registration and integration

In order to register the whole dataset in a geo-referenced coordinate system, a set of starting topographic points given by the Pompeii Superintendence, thickened with a dedicated topographic campaign, was used.

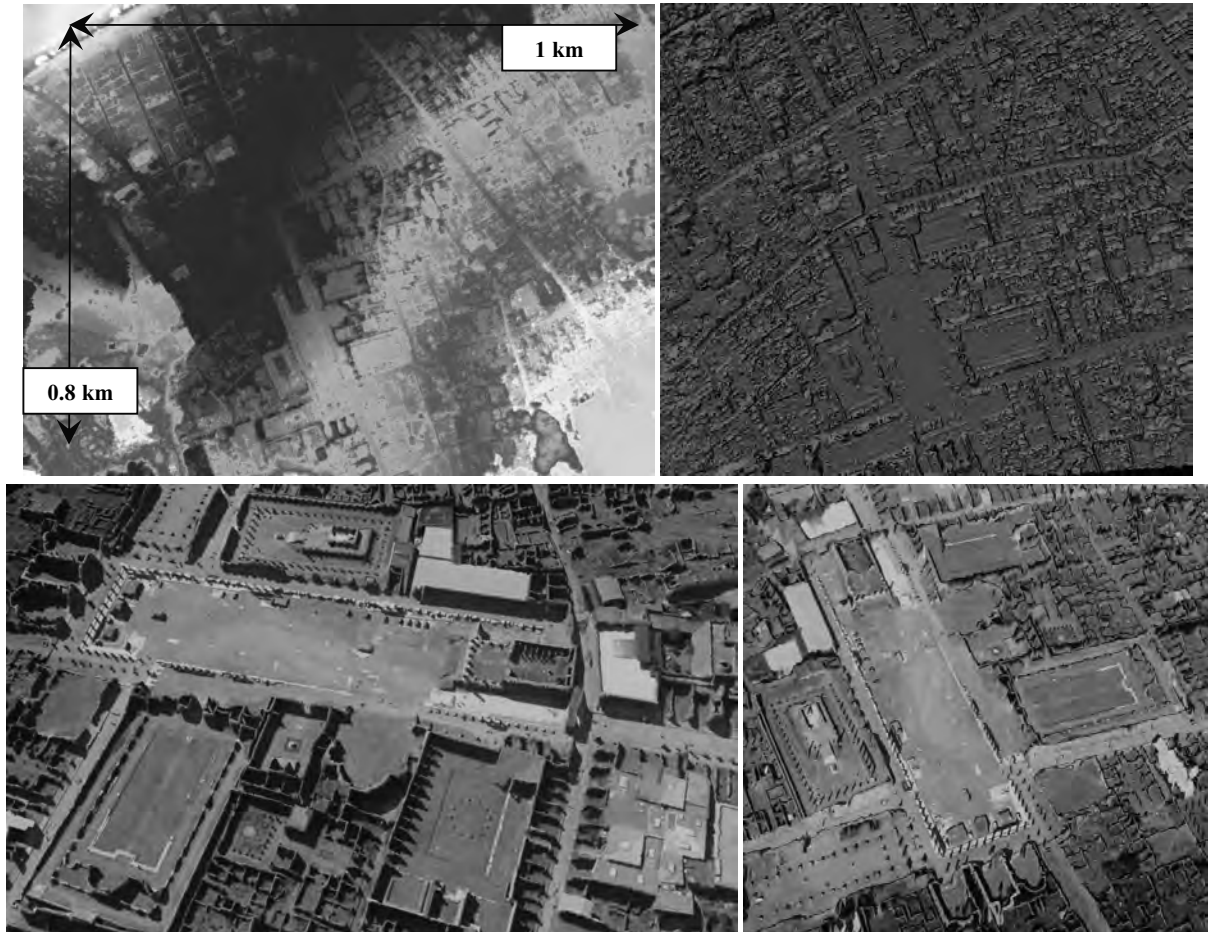


Figure 3: The DSM (18 Mil points) of the archaeological area generated from three aerial images with a multi-photo image matching method, shown in colour-code and shaded mode (above). Two views of the surface model, interpolated at 25 cm and textured with the generated orthophoto (below).

The laser scanning campaign was primarily devoted to create a geometrical framework on which orient each photogrammetric model. For this reason, the two starting scans were acquired from two documented topographic points and all the other scans were aligned on these. The final range model was afterwards roto-translated through the other documented points with a spatial similarity transformation (with the scale constrained to 1). The residual error given at the end of the processing was around 50 cm. The resulting cloud of points (figure 4) was afterwards employed to align each single photogrammetric model and, thanks to redundancy, for checking possible dimensional errors.

For some archeologically interesting large structures, the range data were used also for generating high resolution mesh models such as the ones shown in figure 5 and 6.

## 5. RESULTS

The aerial images provided a dense DSM which was then interpolated at 25 cm to produce a surface model of the entire archaeological area. The model was afterwards textured with the relative orthophoto (figure 3). This constitutes the first low-resolution level of detail of the entire 3D model of the Forum. Despite the fact that the 25 cm DSM smoothed slightly out the small features of the forum (like walls or columns) it is a good starting for a flight-over and as initial visualization of the heritage.

The range data, primarily used to orient all the terrestrial photogrammetric models resulted in a cloud of ca 100 million points (figure 4).

Some areas of particular archaeological interests were also mesh modeled starting from the laser scanner cloud of points, and textured with the acquired digital images. Some preliminary results are reported in figure 5.

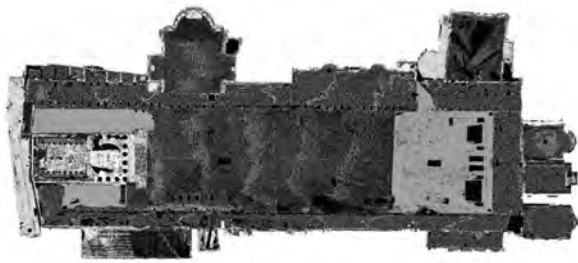


Figure 4: The range data seen from above classified in layers for faster handling and manipulation.

Independently from the possibility of generating different LODs, a special care was given to model optimization. Indeed the models generated from laser scanning were initially extremely detailed due to the high density of geometrical data

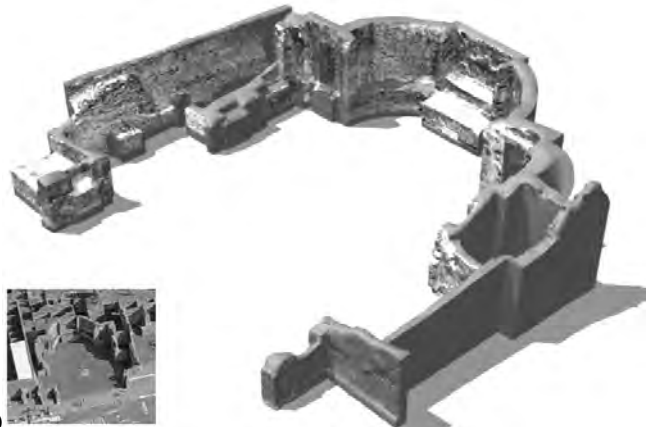
collected from the scanner, but, in order to optimize the following visualization step, the models were then selectively simplified leaving a high geometrical resolution only on the areas indicated by the archaeological team involved in the project.

The level of texture mapping resolution was also considered independently by the geometric resolution for maximizing the level of information associated with any specific artifact. In this way we obtained low geometric resolution and high texture mapping resolution for flat walls with interesting “opus reticulatum” sections, or, high geometric resolution with low texture mapping resolution for complex shapes made with uniform and not particularly interesting materials. The photogrammetric processing of all the 3200 terrestrial images produced 3D models of simple structures (arches, walls, columns) or larger complexes (e.g. temples) (figure 6).

Detailed ornaments, modeled in high resolution with image matching (figure 7), were afterwards integrated with the other low resolution data.



(A)



(B)

Figure 5: 3D model of the Nero Arch (10m x 2.5 m x 7.5m) produced from the acquired range data and textured with digital images for photo-realistic visualization (A). Photo-realistic range-based 3D model of the Lari's temple (27m x 27m x 6m). In the left-lower corner an image of the temple from an oblique aerial view (B).

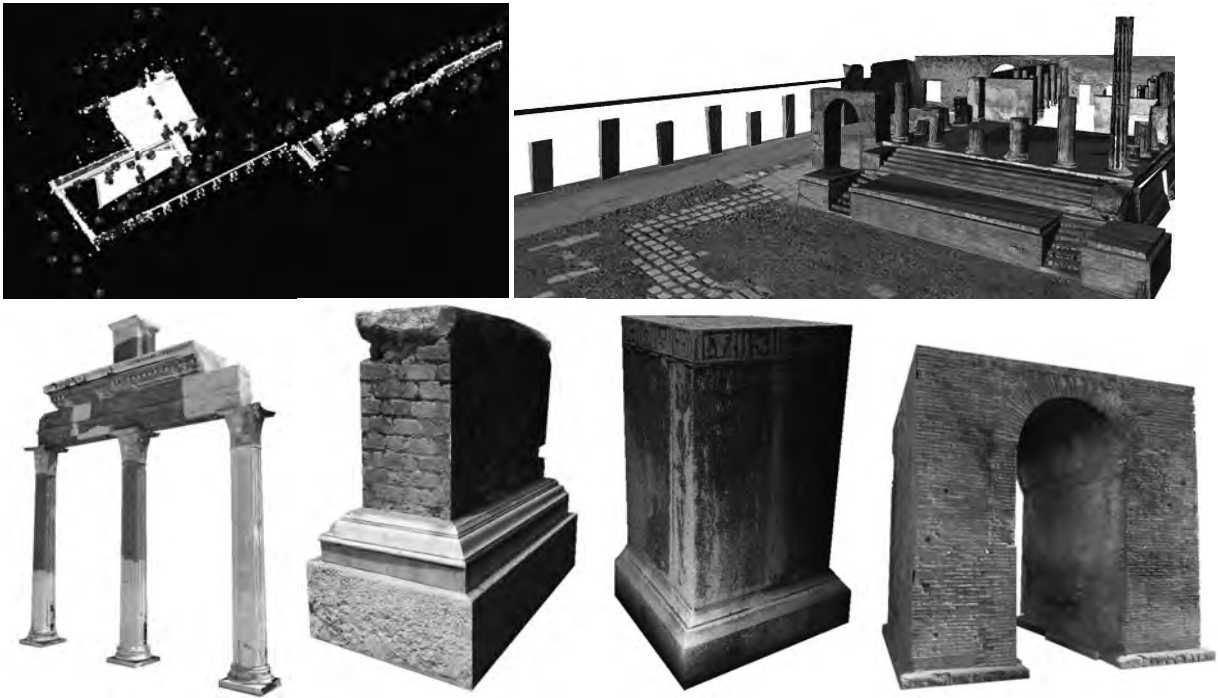


Figure 6: An example of the terrestrial photogrammetric block for the modeling of the mural large structures (Zeus Temple, above). Photogrammetric 3D models of finds, columns and arches.

## 6. CONSIDERATIONS AND CONCLUSION

In this contribution the reality-based 3D modeling project of the Forum in Pompeii has been presented. The first results of the modeling and integration are promising, although practical and reliable solutions for the visualization of the entire 3D multi-resolution model are still under investigation. The integration of multiple modeling methodologies allowed to exploit the intrinsic advantages of each approach each one where best suited. Therefore flat mural surfaces were reconstructed with few points while ornaments and details were modeled with laser scanner or dense image matching. This approach helped also in the generation of the level of details of the final 3D model of the large site. Indeed our approach was planned to be hierarchical by the data source and in the hierarchy, details, precision and reliability increase as we get closer to a find or detail of particular archaeological interest. Furthermore, in the visualization of the large and complex model, low resolution data in one level are overridden and replaced by higher resolution meshes of the successive levels of resolution.

The entire 3D model, since it is geo-referenced, can be easily linked to existing archaeological databases, using the spatial coordinate as query. The data-base model relationship is planned to be implemented in both ways: from the geometrical model to the connected data, for explaining historical and conservation details of a specific artifact in the forum, and from a specific document or philological detail to the corresponding location in the 3D space. This tool is intended as an instrument for helping: a) the complex conservation activity of the Pompeii Superintendence; b) the general archaeological study of the area; c) the explanation of the forum ruins to the common public.

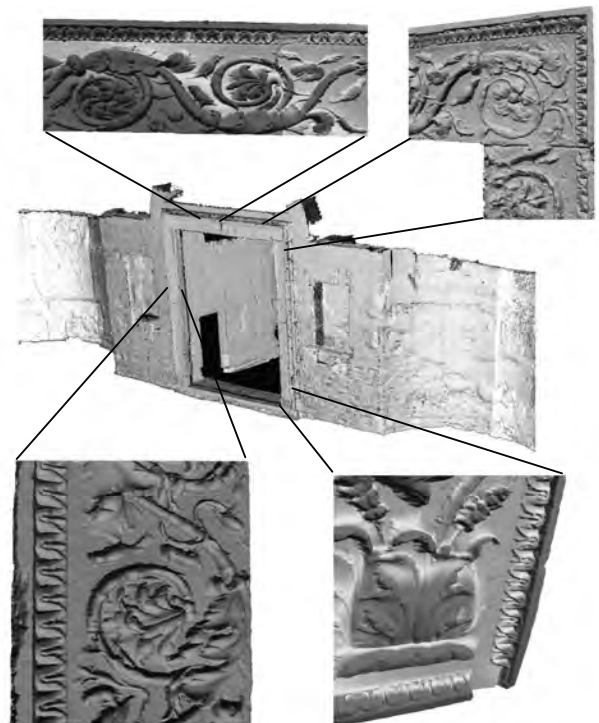


Figure 7: The ornament around the Eumachia door, modeled in high-resolution with a dense image matching and shown in colour-code or shaded mode.



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## INTEGRATED DIGITAL TECHNOLOGIES TO SUPPORT RESTORATION SITES: A NEW APPROACH TOWARDS A STANDARD PROCEDURE

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**KEY WORDS:** Architecture, Topographic survey, LIDAR, Orthophoto, Solid image, Photogrammetry

### ABSTRACT:

LIDAR data integrated with digital photogrammetry today represents one of the most attractive ways of facing the metric surveying of an architectural object. Many papers have illustrated the possibility of building a complete 3D model using just these two techniques. In practice, not many restorers are used to managing 3D models and traditional graphic results, such as plans and sections, are usually required. The paper defines a correct balance between the use of traditional (manual and total station) and innovative (LIDAR and digital photogrammetry) techniques in order to satisfy the usual requirements for the metric survey of an architectural object. A project was carried out to obtain knowledge of a Church in Turin; it was necessary to prepare the survey graphic drawings that would be used for the restoration both of the decorative motives and of the structure of the church. The most important aspect of this work is the integration of traditional topographic techniques with the LIDAR technique. This integration was necessary because of the complexity of the object that was to be surveyed and of the requested short times necessary to realize the survey. The tools implemented in the new Sir-IO software (realized by a DITAG research group of the Politecnico di Torino) were of great help in this work. Thanks to this software it was possible to directly plot the details that were to be surveyed on the realized solid images and orthophotos, thus making the preparation of the survey graphic drawings considerably easier.

### 1. INTRODUCTION

In the last few years, a great deal of experiences have been gained on the use of LIDAR techniques, usually integrated by digital photogrammetry, in order to obtain 3D models of cultural heritage objects (Guerra et al., 2002; El-Hakim et al., 2008).

Ranging from small object to buildings, building complexes, historical centres and natural landscape, the papers presented in many congresses and symposia have demonstrated the possibility of obtaining a complete answer to 3D knowledge and understanding using just these two innovative techniques (Agnello et al., 2008).

It should however mentioned that no costs/benefits analysis have been performed to show the real applicability of the obtained results in practical works and no one has considered that, in most cases, the final users usually require 2D graphical results such as plans and sections.

The setting up of plans and sections by using LIDAR data can be interpreted as a low level usage of them and the obtained results do not have the same quality as the ones obtained using traditional techniques. Furthermore, digital photogrammetry is not the best technique to provide 2D representations by means of plans and sections.

On the other hand, traditional techniques (e.g. direct approaches using distance measurements or indirect approaches using reflector-less total stations) involve remarkable limitations due to poor lighting conditions and inaccessibility of the details, especially when ad-hoc scaffoldings can't be used.

In these situations, a productive integration between traditional and more innovative techniques is advantageous.

In the following sections, a real application of an integrated metric survey of a historical church in Italy is described in detail. A possible solution to obtain the best economic impact and the best final solutions will be shown.

### 2. THE SURVEY OF THE CHURCH OF THE "MISERCORDIA" IN TURIN

Located in the historical centre of Turin, the Church of the "Misericordia" has a rich interior decorated in baroque style and a neo classical façade (see fig.s 1 and 2).



Figure 1: The main façade of the Church of the "Misericordia"

The Church has structural movements which affect the decoration of the interior, therefore a restoration project was financed in order to repair structural weaknesses and to restore the decorative parts.



Figure 2: Inside view of the Church of the “Misericordia”

The metric survey had to fit the needs of a detailed design therefore a final tolerance of 2 cm was adopted (e.g. 1:50 nominal scale). The production of the main plans (fixed at 1.2 m and 8 m above the floor) and of 7 vertical sections were decided on according to restorer requirements. Some practical problems arose during the design of the metric survey. First, the church was continuously open during the survey and permission to place of scaffoldings was denied. The complete acquisition phases had to be completed in no more than two weeks and no special illumination was allowed. Finally, all the interior decorations on the walls are made of yellow, brown and black marble.

Considering all these constraints and the necessity of obtaining the required tolerance of 2 cm, even in the upper part of the church (more than 25 m above the floor), the combined use of digital photogrammetry and LIDAR acquisition for all the details not on direct contact with a human operator represents the only possible solution. Only the traces of the plans and of the sections were surveyed using total station. Manual measurements were made of the hidden details, as this approach was considered the most efficient in this particular case.

All the steps of the survey are presented in the following sections in order to point out the correct integration and the obtained final results.

**2.1 The first order network**

In each metric survey, a first order network had to be fixed in order to define a local 3D coordinate system and to control the error propagations under the fixed 2 cm of tolerance (at 95% of probability). In order to reach the last goal, estimated accuracies of less than 1 cm had to be reached on the points of the network. Considering that the control network had to circumscribe the survey space, the most of the points were placed inside the building. Classical angle and distance measurements were therefore performed for the planimetric survey and geometric levelling was used to define the network in the third dimension. The planimetric first order network was made up of 22 control points (see fig. 3 and 4) permanently materialized on the floor with metallic nails and a suitable sketch was realized for each of them.

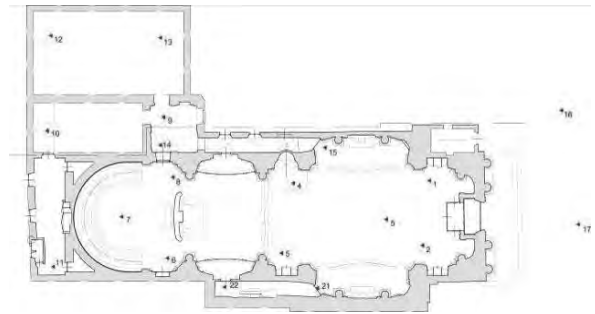


Figure 3: Low ground map with indication of the control points

The survey scheme that was adopted is the free topographic network realized with a number of measured angles and distances that is exuberant with respect to the minimum geometric constraint in order to estimate the obtained precisions.

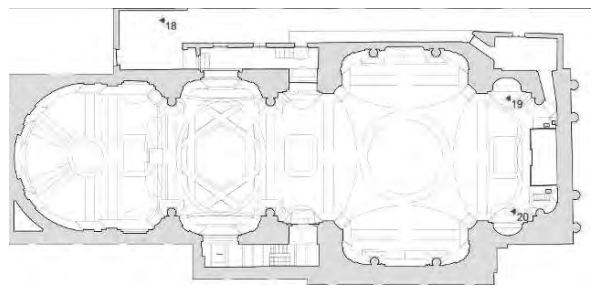


Figure 4: First-floor map with indication of the control points

The Topcon GPT 8201A total station and an electronic level LEICA NA2002 were used for the measurements. All biases were eliminated using hardware and ad hoc solutions. The coordinates of the control points were estimated with a least square adjustment (Starmet by Starplus Technologies), obtaining precisions that were suitable for the following field survey phase. The local coordinate system has its origin in the point 2 (X = 100 m, Y = 100 m and Z = 100 m) and the line passing through point 1 defines the y-axis.

The scheme of the measurements and the standard error ellipses on each control point are represented in figure 5.

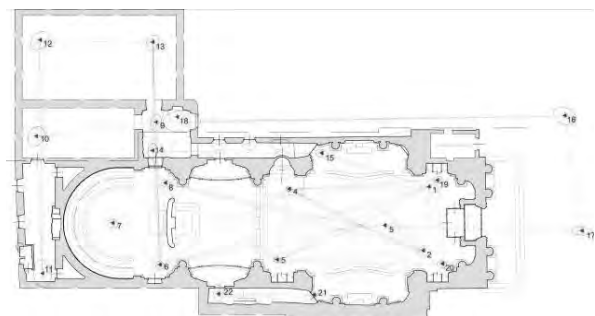


Figure 5: Scheme of the measurements and of the standard error ellipses of the control points (110X zoom)

Control points	$\sigma_x$ [cm]	$\sigma_y$ [cm]	$\sigma_z$ [cm]
1	0.081	0.000	0.023
2 [origin]	0.000	0.000	0.036
3	0.079	0.013	0.014
4	0.083	0.012	0.019
5	0.050	0.094	0.065
6	0.146	0.155	0.089
7	0.157	0.191	0.033
8	0.137	0.153	0.045
9	0.301	0.184	0.068
10	0.362	0.292	0.098
11	0.487	0.319	0.085
12	0.335	0.317	0.033
13	0.279	0.220	0.044
14	0.276	0.168	0.059
15	0.142	0.228	0.063
16	0.304	0.405	0.055
17	0.141	0.385	0.083
18	0.389	0.666	0.074
19	0.125	0.173	0.022
20	0.126	0.173	0.023
21	0.879	0.657	0.057
22	0.651	0.897	0.031

Table 1:  $1\sigma$  estimated values of the control point coordinates

These results show the correspondence between the measurements and the statistical precision model. The achieved precisions are a lower order of magnitude than the tolerance required for the field survey.

## 2.2 Traditional surveys

In order to acquire the needed points for the realization of the drawings, a traditional survey was conducted using a total station. All the station points were located on the vertexes of the control network. A LEICA TPS 805 total station was used for all the detail surveys.

The surveyed points were integrated with direct measurements and interpreted in order to draw the required plans and sections. Figures 6 shows the intermediate results of the instrumental survey and the final drawing of a plan detail, produced after integration and interpretation following the traditional guidelines for architectural representations.

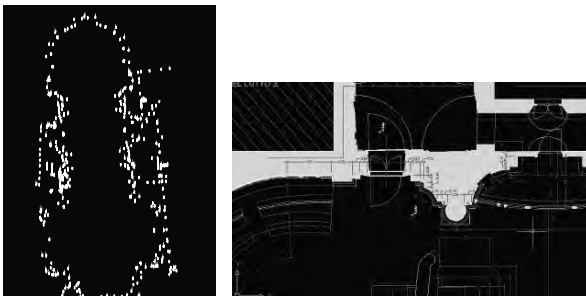


Figure 6: Surveyed points and final drawing after integration and interpretation

The complete surveys of the plans and sections required three days and the results were used for the drawing phase at the end of each day in order to speed up the interpretation and representation phases.

The completion of the sections and plans always requires knowledge of the details which are visible in the direction of the section planes, therefore particular attention was paid to record all the visible details.

## 2.3 Photographic rectifications

The photographic rectification technique was employed to describe some decorative parts of the church. The use of this technique was limited to some particulars of the church (the ones that could be approximated to plains), such as the side chapels and the confessionals.

The digital images that had to be rectified were acquired using the calibrated Canon EOS 5D camera (12.8 Mpixel); the points necessary to define the mean plains for the rectification process were measured using the total station. The analytic photographic rectifications were realized using the Archis 2D software (Galileo Siscam). The use of a calibrated camera and experimental software realized by the DITAG research group allowed the elimination of the residual radial distortions from the acquired digital images. The portions of the church that were subjected to photographic rectification are indicated in figure 7.

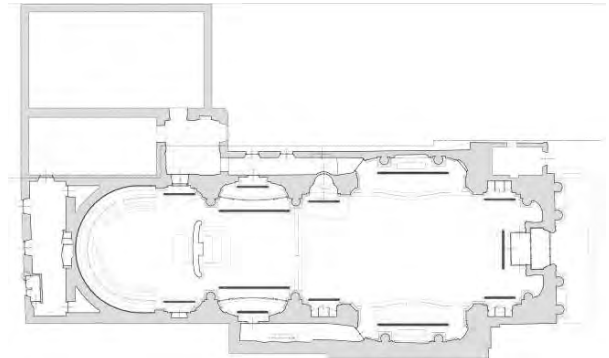


Figure 7: Positions of the images (red lines) subjected to the analytic photographic rectification process

An example of a rectified image and the subsequent digitization process is reported in figure 8.

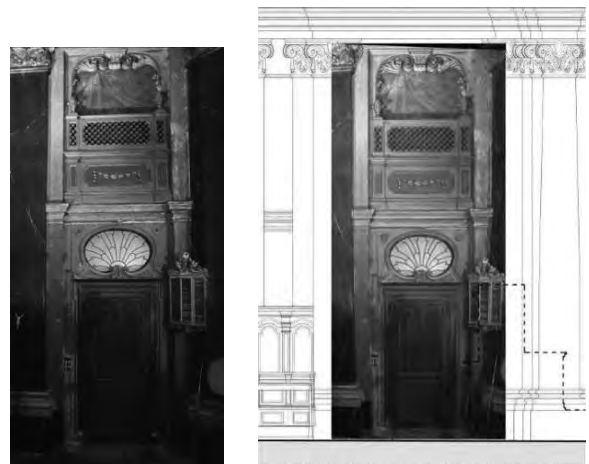


Figure 8: Original photo and rectified photo employed for the representation of the decorative elements for the section representation

Thanks to these methodologies it was possible to provide the designers with a useful product for the representation and documentation of some internal parts of the Church. The methodology was acceptable because the visible parts were not subject to the strict tolerance of the survey, therefore walls that are not perfectly plane can also be recorded in this way.



Figure 9: Extract of a section with decorative elements recovered from rectified images

**2.4 LIDAR and digital photogrammetry integration**

Both LIDAR and Digital photogrammetry are techniques that can allow the acquisition of the primary data in a very short time and they therefore seem to be a correct approach for a survey.

As far as LIDAR is concerned, the subsequent registration, segmentation and modelling phases are more expensive in terms of time and require professional skills. Digital photogrammetry requires great deal of time and experience to orient the images and to extract the needed geometric information from stereo-models due to the complexity of the object which makes the necessary to carry out manual extraction of the geometry.

LIDAR primary data can however offer some useful analysis instruments in a complete automatic procedure and digital photogrammetry can use great deal of information from LIDAR that is useful to obtain oriented images in an automatic way and to map the images on the point clouds. In addition, a new instrument, based on a multi image correlation was used to describe the main altar of the church.

**2.4.1 Data acquisition:** A Riegl LMS Z-420 laser scanner (figure 10), a TOF instrument, was employed. Table 2 summarizes the main technical details of the used instrument.

Measuring range	up to 350 m
Minimum range	2 m
Distance measurement accuracy	± 5 mm
Measurement rate	3000-9000 pts/sec
Vertical Scanning range	80°
Horizontal Scanning range	360°
Weight	14.5 Kg

Table 2. Key specifications of the RIEGL LMS-Z420

In order to obtain a good quality in the detail description, a scanning interval of 50 mgon was employed in all the scan positions. Only the pipe organ was scanned at a 35 mgon scanning resolution; seven different scan positions were taken in the church.



Figure 10: Vertical and horizontal acquisitions

The wall decorations of the church were acquired using the laser scanner in the vertical position while the vaults were surveyed putting the instrument in the horizontal position (see fig. 10). Figures 11 and 12 show the areas that were acquired in each scan position.

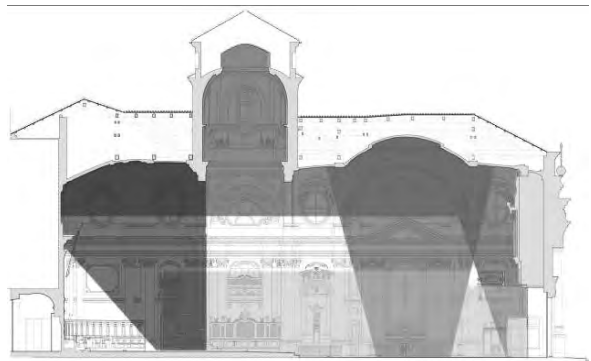


Figure 11: Surveyed surfaces in scan positions 1-2-3-4

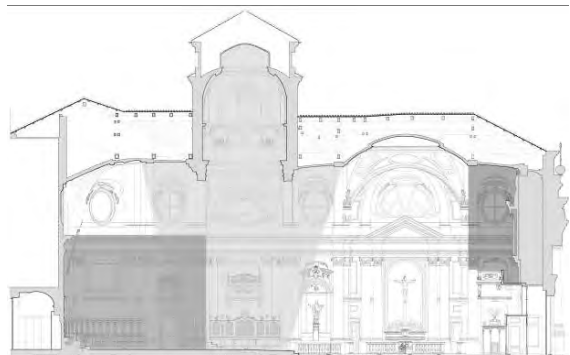


Figure 12: Surveyed surfaces in scan positions 5-6-7

Metric images were acquired using an high resolution digital calibrated camera (Nikon D1X, 18 MPixel, equipped with 14 - 24 mm lens) which was mounted onto the top of the LIDAR instrument. In the survey, both 14 mm and 24 mm lens were employed in the image acquisition, in order to achieve approximately the same field of view in the laser scanner and

the camera acquisitions, considering the different fields of view of each scan.

During the laser scanner acquisition, several reflector markers (see fig. 13) were placed in the church. Their positions were chosen in order to guarantee a minimum number of common points (at least 5) for each adjacent scan-pair with a suitable localization and a good geometrical strength (locating them at different heights). All the markers were measured by the total station and referred to the coordinate system defined at the beginning of the survey.



Figure 13: Reflector markers employed during the laser scanner survey

**2.4.2 Data processing:** The first step of data processing was carried out using the RiscanPro Software. Thanks to this software, each scan position was relatively oriented to the photographs (mounting). All the other processing steps were performed using the Sir-IO software, which was recently realized thanks to the cooperation between the Politecnico di Torino spin-off SIR s.r.l and the Geomatics research group of the same university. Using this Software, the point clouds were filtered through a median filter (Bornaz et al., 2001) in order to reduce the data noise. The radiometric information was then linked to each scan, in order to obtain coloured point clouds. The scanner yields a point cloud in the sensor coordinate system (x,y,z) for each position.

The data sets of all the scan positions were oriented relative to each other (traditional registration); moreover, using the reflector marker coordinates, an absolute orientation of all the scans was performed using the “laser triangulation algorithm” (Bornaz et al., 2002) implemented in the Sir-IO software (figure 14). The final result was a complete point cloud of the internal surfaces of the church in the local topographic system (figure 15), achieving a  $\sigma_0 = 1.19$  cm with respect the final tolerance of the survey.

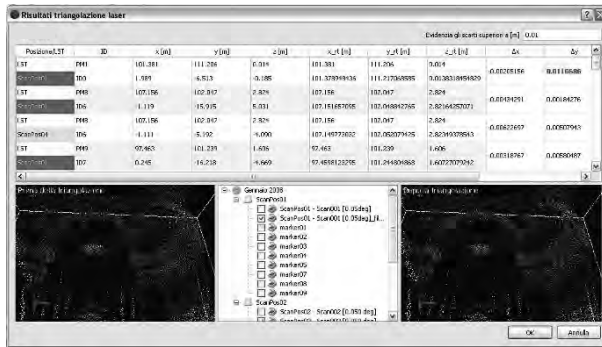


Figure 14: Laser triangulation in the Sir-IO Software



Figure 15: Complete coloured 3D model of the Church

It is well known that a point cloud of a church is useless in restitution work; it is very difficult to extract coherent information from millions of points without a segmentation and a modeling phase.

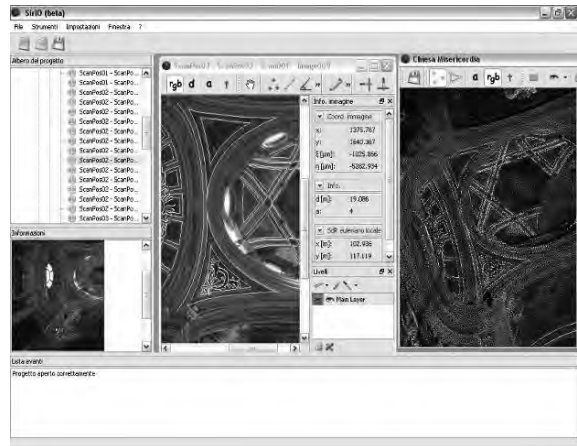


Figure 16: Plotted details in a solid image

For this reason, in the last few years, the Geomatics research group at the Politecnico di Torino has developed new instruments in order to make the use and the extraction of suitable information from laser scanner data easier when no complete 3D model is required.

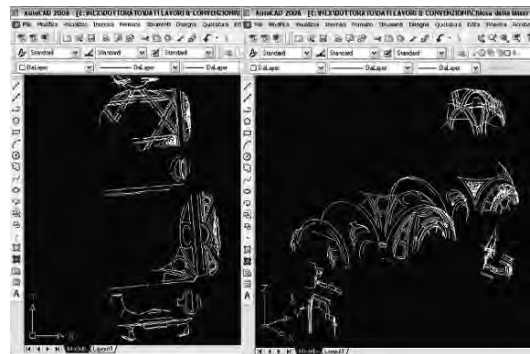


Figure 17 : 3D details exported in Autocad

In some ways the Sir-IO software represents the last step of this work because it allows solid images (Dequal et al., 2003) and

solid orthophotos to be generate. Furthermore, it is possible to survey the required details just by redrawing the contour of the objects on these products, as shown in figure 16. With reference to the Misericordia church, about 70 solid images were created in order to document all the internal surfaces of the church. Moreover, several solid orthophotos were realized to document and accurately describe the vaults and the church ceilings. From these products, it was finally possible to draw the parts to be projected in the representation of the longitudinal and transversal sections and to describe the fine decorations of the upper parts of the church with the required tolerance.

The information obtained from the Sir-IO software, such as distances, angles, point coordinates, and in particular the vector plotting, were finally exported in a CAD software (figure 17) in order to merge this information with the information achieved in the topographic survey in order to make the final correct drawings (see fig.s 18, 19 and 20).

The solid images were also suitable for the evaluation of the deterioration of the walls due to water damage.



Figure 18: Longitudinal section 1:50 (not in scale)

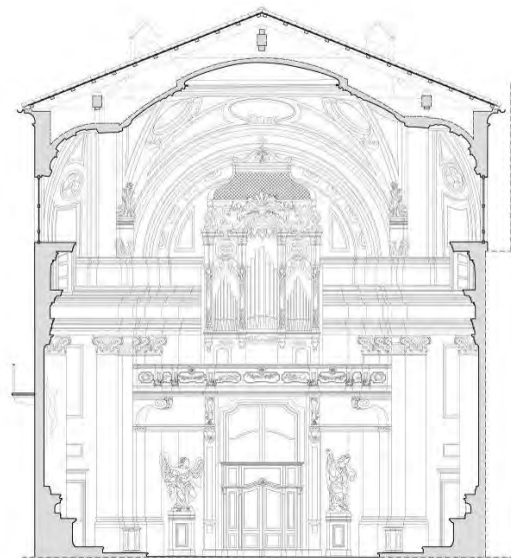


Figure 19: Screen shot of a part of the 3D model of the Church [left] and corresponding drawing (transversal section 1:50, not in scale) [right]



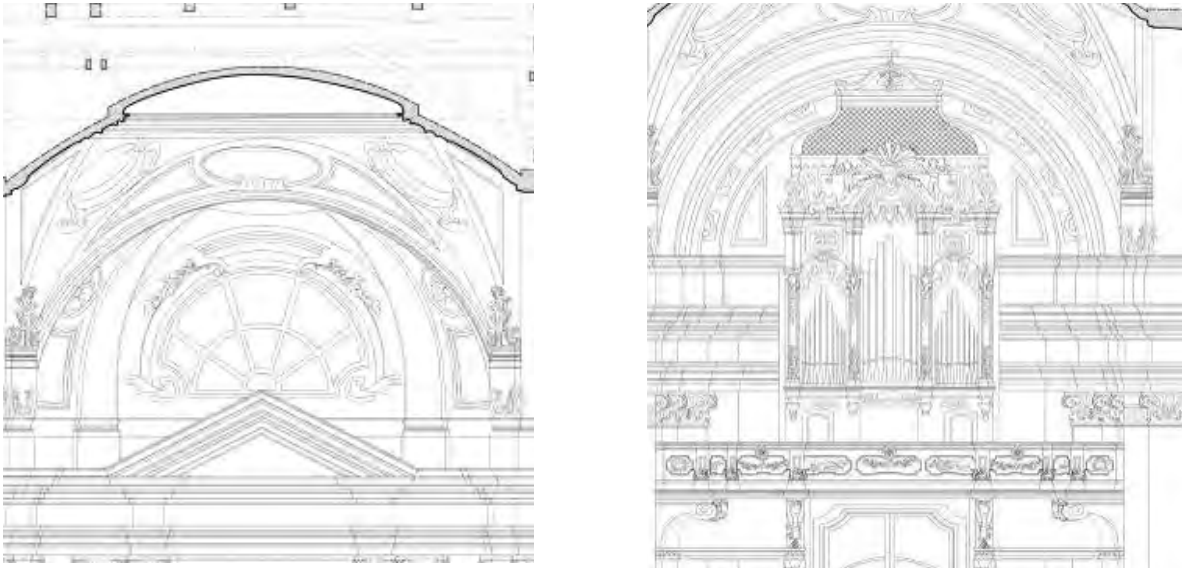


Figure 20: Decoration details 1:50 (not in scale)

### 3. MAIN ALTAR SURVEY

One of the most important objects in the church is the main altar. It would have been difficult to survey the main altar using the traditional techniques because of the irregular shapes of all its components. A detailed survey was performed using a new digital photogrammetric instrument based on the multi-image correlation: the Z-Scan (by Menci Software - Italy). A calibrated bar allows many images to be taken with a regular and known base length.



Figure 21: Z-Scan image acquisition

An automatic software carries out the relative orientation of the images (with a bundle adjustment approach) and the point matching by considering all the possible images. During the XXI ISPRS congress (Beijing, July 2008), the authors demonstrated that multi-image correlation can give point clouds with the same density and accuracy as the ones usually acquired with the LIDAR approach. The main advantage is the low cost of the acquisition instrument (a metric camera) and the scalable reachable precisions (by varying the base/distance ratio).

Figure 22 shows the results of the multi-image matching of the main altar.

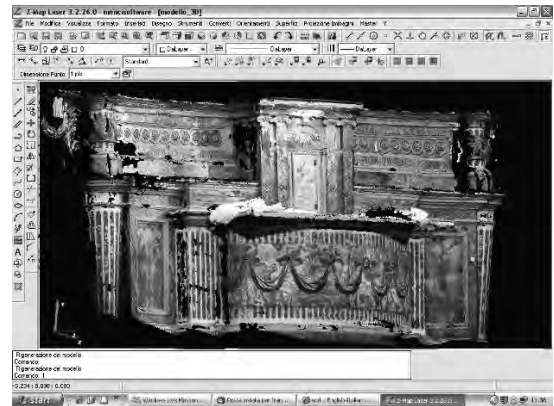


Figure 22: 3D point cloud obtained by the Z-Scan

### 4. SURVEY DOCUMENTATION

A complete documentation of a survey is currently a mandatory task that has to be completed at the end of each survey. First, it should be clearly stated that the final drawings, 3D models etc. are not the results of the survey, but just a way of representation. In fact the final drawings (see fig.s 18, 19 and 20) do not allow complete accessibility to the original survey data that are useful to integrate, substitute and extend the acquired data. The final drawings and the 3D models do not allow a new elaboration of the acquired results and therefore do not allow the possibility of using the advantages obtained from the new data elaboration method which can be defined many years after the acquisition of the primary data. It is possible to state that a correct documentation of the survey involves the recording of the used coordinate system and of the primary data. The coordinate system is defined by the control network points, therefore the measurements used to compute their coordinates and the final sketches have to be saved.

The primary data change according to the techniques that are used. In the case of direct measurements, the filled sketches and the original measured distances have to be saved. In the case of total station measurements, all the angles and the distances have to be recorded according to the technical specifications of the used instruments. As far as a photogrammetric survey is concerned the original images, the calibration data of the used cameras and the control points used to orient the images have to be saved. Finally, in the case of LIDAR surveys all the original files have to be recorded with the control points used to recover the final coordinate system and the sketches demonstrating the taking points for each scan. In order to complete the documentation a simple metadata structure is also needed in order to give the authors, their addresses, the time when the survey was made and the extension of the survey.

## 5. CONCLUSIONS AND FUTURE DEVELOPMENTS

An integration between traditional and innovative techniques in an architectural survey has been presented in this paper. The correct balance between the four different used approaches (manual measurements, total station, digital photogrammetry and LIDAR) is influenced by the size of the object, the lighting conditions, the materials, the field restrictions and the tolerances. The kind of required final representations (e.g. plans and sections, 3D models, etc.) also influences the number of surveyed points and of the usable techniques. The LIDAR technique and digital photogrammetry, thanks to new management instruments (e.g. solid images), can also be used when 3D models are not the final products required by the end user. The example described in the previous sections shows that a correct use of the LIDAR technique and of digital photogrammetry can speed up the acquisition phase and give all the information needed for a complete graphic representation of a surveyed object.

The LIDAR technique and digital photogrammetry in particular can be used not only when 3D models are required but also to help traditional techniques to speed up the survey of the inaccessible points without performing the heavy segmentation and modeling phases, that at the present state of art, require a huge human intervention. The Research Group at the Politecnico di Torino activated a new research activity concerning the possibility of merging digital photogrammetry and LIDAR segmentation in order to reach a higher degree of automation. The basic idea is to extract, from the oriented images, radiometric edges which usually match geometric break-lines (the results of the segmentation) in order to drive the segmentation algorithms towards affordable solutions without human validation and correction intervention. The success of this research goal will allow a change in the strategy of the metric survey and a different integration between traditional and innovative metric survey techniques.

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## THE IMPORTANCE AND CHALLENGES OF E-DOCUMENTATION FOR THE CONSERVATION FIELD

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**KEY WORDS:** laser scanning, 3D digitization, quality assessment, accuracy, conservation of cultural heritage.

### ABSTRACT:

The present paper comprises preliminary work instrumented for a project with a main objective to correctly document objects with archaeological and historical value using digitization and software post-processing. The objects belong to different chronicle periods and present significant differences in geometry, materials, style, and essence/texture. The present paper treats the importance of documentation for the conservation field, as well as the indisputable importance of modern technology in solving problems related to that field such as replication, reconstruction, and dissemination. It is, also, vital that digitization must generate a digital replica of an archaeological object with, if possible, 100% accuracy. For this purpose we will present some digitization results and the challenges faced towards establishing optimum similarity of the digitized vs. the original object.

### 1. INTRODUCTION

In this paper we present preliminary work instrumented for a project aiming primarily at documentation for conservation. The project has two objectives: to digitize a large number of archaeological artefacts available at the Museum of Kykkos Monastery and to develop a web based database management system that will allow retrieval based on descriptive and geometrical characteristics of the artefact. An important constraint is that the 3D digital copy of each artefact must be extremely accurate. Therefore within the framework of the project we will also develop techniques to measure and improve the digitization of archaeological artefacts.

Documentation for conservation, among other reasons, has been receiving a great deal of attention over the past years. Researchers have worked towards documenting several Michelangelo's statues (Levoy, 2000), the great Buddha statue (Miyazaki, 2000), coins and ceramics (Mara, 2007), wooden stamps (Seulin, 2006), even ancient cities (Zach, 2001) and these are just a tiny set of examples. Documentation is very important as it allows implementation of several applications such as virtual reconstruction of heritage sites (Beraldin, 2005), fast fragment assembly (Cooper, 2001), archiving and retrieval, web-based cultural heritage (Zara, 2004), etc.

The continuously increasing need for cataloguing numerous archaeological artefacts of museum collections in a well documented database led us to start the presented project. The aim of the project is to create software capable to lodge the various data that an archaeological object can reveal, rendering in that way easier the study from the scholars. In these terms, an indispensable part of such a project consists of the digitization of the objects under examination, for a more spherical and completed documentation. Furthermore, such a work will facilitate the conservation job, causing less erroneous decisions from the part of the conservators that at times arrive to destroy an archaeological residuum. Here by, we will present the 3D digitization of four objects. We present the procedure; the challenges, the results as well as the problems emerged.

### 2. DOCUMENTATION FOR THE CONSERVATION

Conservation, from the act of interfering directly on the object, till the exhibition and the right storage, has to be done in the most accurate and well-documented way.

Maybe the most difficult part of this process is the conservator's decision of how the object will look like after the intervention, how is the new shape going to be and why. This is mainly an ethical decision to be made by the operator, considering the aesthetical and historical value of an object.

A lot of wrong decisions have been taken during the history of restoration of the cultural heritage (including monuments, objects, architectural complexes etc.) regarding the decision of how an object should be restored, respecting the object itself and at the same time reflecting the principles of the restoration theory. The case of interfering in a wrong manner could be considered more admissible in the past, mainly due to the scarcity of experience and lack of technology. Lots of times, conservators had to had undone a wrong former restoration and proceed with a new one. The lacking of documentation renders this job even more difficult and with a great responsibility among the people related or not with the field, since an object of culture is to be considered worldwide cultural heritage of the mankind.

Nowadays, the science of conservation, even though constantly enriched with new knowledge, is considered to be mature and in combination with the modern applied technology, initially oriented in other fields, we have no room left for repeating the mistakes of the past regarding our cultural heritage. This is probably the most important facility the digital method offers to the archaeologists and conservators: *the possibility to work in an iconic reality*.

Today for the charting of archaeological artefacts the following three methods are mainly in use:

1. laser scanner
2. photogrammetry
3. classical/manual way

3D digitization is a non-contact, non-destructive method and once completed, the object can easily be recorded, stored, shared, studied, restored and conserved either in its geometry or its texture part, and all these in the space of a virtual reality. In case that the object under examination needs to be restored, the decision that the operator of the field must take, can be done digitally, with the possibility to be repeated several times, shared with other professionals and finally decided in a more scientific way. Using, for instance, CAD techniques an excellent restoration of an archaeological artefact or masterpiece can be achieved. Operating this way is obvious that we avoid repeating past errors that may cause further destruction to our heritage. Furthermore, the possibility of reconstructing the geometry of an object with proven accuracy provides us with more metrological information easily retraced, valuable for the scholars.

Since it is not the purpose of the present paper to proceed with the comparison between the aforementioned methods and their subcategories, we restrict only in saying that the laser scanning method is the quickest and the most accurate one out of the three techniques. Combined with post-processing, excellent results can be obtained regarding the geometry of the scanned object, metrological data, texture details, color, engravings and any kind of decoration presented.

### 3. THE PROCESS

In this section, we describe the equipment used for the 3D digitization and the post-processing and the various factors of the scanning process.

#### 3.1 The equipment

For 3D digitization, we have used the laser scanner Konica-Minolta VI-9i, a rotating stage, the polygon editing tool and Geomagic Studio.

Konica-Minolta VI-9i is a considerably light 3D laser scanner weighing only 10kg. It is a high speed, high precision scanner that has measurement accuracy  $\pm 0.5\text{mm}$ , that scans using the triangulation principle and requires only 2.5 seconds per scan to acquire accurate texture mapped range data. Each scan comprises of 640x480 range points, which means acquisition of about 300K points per scan, and one low resolution 640x480 photograph that is directly texture mapped onto the range points. It can scan easily small, medium and large items as it contains three lenses (tele, middle and wide), one for each size, respectively. During the experiments we have used two lenses, as we scanned small and medium size items. The scanner is also quite flexible, in the sense that it is mounted on a tripod therefore it is quite easy to make height and orientation adjustments.

In order to make it even easier to scan the archaeological artifacts we have used a rotating stage (turntable). The advantages gained by using the rotating stage is that multiple scans of the artifact can be acquired extremely fast, without changing the setup, which are automatically aligned saving the user of a significant amount of scanning and post-processing time.

The polygon editing tool (PET) is complimentary to the laser scanner and allows single scanning or step-scanning using the rotating stage. During step scanning PET synchronizes the scanner and the rotating stage.

For post-processing we have used Geomagic Studio. Post-processing includes scan alignment, merging, closing holes, decimating, smoothing, and other operations.

#### 3.2 The scanning process

During the scanning process (Figure 1) the first step was to setup the equipment and set the scene. During scene setting, we had to decide whether it is appropriate to use the rotating stage, how far the scanner should be positioned from the artifact, whether it should be positioned on the same height as the artifact for a horizontal view or higher for a "sky view". The scanning angle is a considerably important factor as when the laser beam is not returned back to the scanner, we end-up with holes in the range data. Usually the reason for holes is occlusion of certain regions of the object; this is fixed by scanning the object using different angles with respect to the scanner in order to eliminate such occlusions.

In addition, a decision had to be made on how many step-scans should be done when the rotating stage was to be used. For example when we initially tried to scan the tripod salver (Figure 3), we have used a rotation angle of 90 degree resulting to four rotations. Because the object has a considerably flat top and quite long legs the scanner could not digitize it correctly, providing a large hole and missing one leg. We speculate that the reason is bad focus. The solution to this problem was surprisingly simple and was just to decrease the rotation angle to 60 degrees which resulted to six aligned scans.

Finally, whether more scans should be done e.g. scan, also, the bottom of the artifact or whether the hole that will occur will be small enough to be accurately closed during post-processing, had to be decided. As it is not the objective to analyze how these decisions are made, we would like to just briefly mention that all the decisions are based on heuristics based on previous experience and the geometry and size of the current artefacts. In a nutshell, as the objects were small and their geometry allowed it we have used the rotating stage in all cases and scanned separately the bottom of the artifact because it composed of important information of both texture and geometry.



Figure 1: The scanning setup. We can see the 3D scanner, the rotating stage and the artefact.

Furthermore, before starting to scan we decided to use artificial reference points to enable correct alignment of the all-around scan and the bottom scan, because the artifacts did not have any pronounced features that could aid the alignment process. At this point we had to be careful as the archaeological artefacts could be damaged. The reference points were created using blue tack which is plasticine like adhesive that can be bought by any

office supply store and can be easily removed without a trace and is reusable.

The whole process of scanning four artifacts, including preparation, lasted about three hours. During that time we scanned, evaluated the results, accepted them or rejected them and rescanned. The post-processing time required was about two hours per scanned artifact.

#### 4. CASE STUDY

The objective of the study was to evaluate the potential of the existing technology for accurate documentation of archaeological artefacts and how documentation helps conservation. In this section, we describe the case study including the objects, analyze the challenges and show the raw and final results.

##### 4.1 The objects

The first decision that we made, in the preparation stage, was the selection of the objects to be scanned. Having intention to examine the potential of the scanner, we have chosen different kind of objects concerning their geometry, texture, color etc.

The objects selected are the following<sup>1</sup>:

- A tripod salver of the Red Polished Ware (reg. number Δ 0292), dating in the Middle Cypriote I-II (Middle Bronze Age I-II), 1900-1725 B.C. (Figure 2).
- A juglet of the Red Polished Ware (reg. number Δ 0413), dating in the Middle Cypriote (Middle Bronze Age) (Figure 3).
- A juglet of the White Painted Ware (reg. no. Δ 0425), dating in the Middle Cypriote II-III (Middle Bronze Age II-III), 1800-1600 B.C. (Figure 4).
- A juglet of the Black Polished Ware (reg. number Δ 0429), dating in the Middle Cypriote II (Middle Bronze Age II), 1800-1725 B.C. (Figure 5).

Figures 3-5 show the excavated object and the restored object. It is quite clear that the operator that undertook the restoration did major alterations on the initial object. The objects in figures 4, 5 had to “suffer” a lot while there is no guarantee that the restoration was correct.



Figure 2: Tripod salver-Red Polished Ware. Physical model. General View.



Figure 3: Juglet of the Red Polished Ware. Physical model before restoration and after restoration.



Figure 4: Juglet of the White Painted Ware. Physical model before restoration and after restoration.

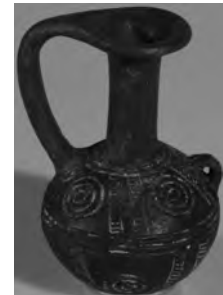


Figure 5: Juglet of the Black Polished Ware. Physical model before restoration and after restoration.

##### 4.2 Challenges

Although all four artefacts belong to the Middle Bronze Age and there are made out of clay, they display differences easily seen by naked eye.

Forthwith, they represent some very interesting aspects from the conservation point of view, since none of them is complete, but all of them “suffered” restoration of a smaller or larger scale. This is one of the challenges we apposed. Luckily, the restoration made can be seen, at least from an expert, and can be understood. Also, for the present objects it happens that a photograph was taken before restoration. Similar situations from the past in which, though, there is no documentation prior the restoration and the last one can not be distinguished by naked eye, they may create confusion or false pictures about the past’s material world. Some questions raised on this issue are: Can the restored part be correctly identified from the digital counterpart

<sup>1</sup> All of the objects come from Cyprus and for now they are kept in the restoration laboratories of the Museum of Kykkos, in the appropriate climatic ambience.

of the object? Also, how can we digitally restore missing components of the artefacts using several guesses?

Another challenge concerns the texture provided by the scanner and its comparison with the reality. Even though clay is the main material used for the objects under question, clay's composition varies a lot from one to another object, in its porosity, admixtures, and grains and generally in its composition. Towards this direction, the capacity of the laser scanner in the depiction of the details has been tested.

It is, also, very important from the archaeological point of view to consider the quality and accuracy of the scanned product and the symmetry analysis of the objects. We have measured manually and in the minutest possible way the objects. After the scan, we compared our results with the measurements given by the software. It was obvious that the laser scanner's product was quite accurate. Regarding the accuracy, the 3D laser scanner is an excellent way of obtaining the good quality in the geometry of an object, which has several aspects such as the body curves, profile-lines, the inclination of the rim, the shape and cross-section of the handle etc. at least for this category of objects. Nevertheless it is not perfect, as the results exhibit.

All the points mentioned above, are important for the scholars occupied with the study of the pottery. These details are difficult to obtain with the manual design of the object and help the archaeologist to date an object, to classify it from a stylistic point of view and according to its shape etc. In general, a large quantity of information can be obtained that will facilitate the study of the object.

A challenge of extreme importance is quality assurance. Archaeologists state that it is very important, when documenting, for the digital object to be, if possible, 100% similar to the physical object in order to be scientifically useful. Therefore an objective is to develop a protocol in order to measure the similarity of the digital object with the physical object. The protocol must provide a degree of certainty regarding their similarity and feedback on the problematic region(s) in order to improve the digital object. Working towards that direction various problems arise. What should be measured on both objects in order to establish the similarity? What is the contribution of texture? What criteria govern the importance of geometrical features? How can we judge that feature A is more important than feature B?

Also, 3D digitization can be very useful for wheel-made ceramics. The object being scanned while rotating around an imaginary vertical axis is like reproducing its construction technique on the first place since, this is the logic followed for the production of wheel-made ceramics. Making a study with this orientation we may create a database (or renew and amplify the existing ones), in which the contour of the ceramics is ascribe with every detail.

### 4.3 Results

After obtaining the aligned scans, using the rotating stage, we have merged them and later on aligned the resulting all-around model with the bottom scan. In order to align, we have used manual alignment. Manual alignment requires selection of three corresponding points, preferably creating a triangle, from each the two models to be aligned. In order to select good points, the object must have pronounced features that exist in both scans or we must create artificial reference points. In our case we had to create artificial reference points prior to scanning. These points were used to correctly align the scans and were deleted during

post-processing. Figures 6, 7, 8, 9 show the raw scans, different views of the digital model and the physical model.

Even though post-processing was aided significantly by the simplicity of the geometry of the artefacts, holes were created under the handles. In addition, the juglet of red polished ware (Figure 6) had three small rings that were scanned closed and had to be restored during post-processing. Furthermore, its digitized rim was distorted.

Despite the aforementioned problems the digital models were overall very close to their physical counterpart, the 3D scanner has produced quite different texture than the original. In addition the texture was affected significantly by the room's lighting that created darker and lighter regions. Even though this problem can be fixed if special lighting conditions are induced, lighting control is not always possible and practical.

In addition the digital models are composed each of about 300K faces. This is an absurd number for such geometrical complexity. It makes it hard to share the models and harder to implement interesting applications such as a web-based interactive virtual museum. But as decimation removes important details for the archaeologist and further distorts the texture, we have decided to keep the initial number of faces (Figure 7).

A nice result produced was that the restored parts (Figure 2, bottom) are clearly visible on the digital models. This is quite important for the archaeologist as it is preferable that the restored parts to be removed during digital processing.

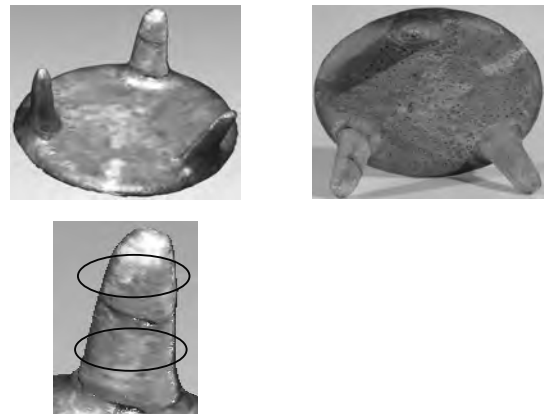


Figure 2: Tripod Salver. Left the digital model, right the physical model, bottom the restoration mark.





Figure 3: Juglet of the Red Polished Ware. Top: The raw scans with the artificial reference points visible. Middle: Two views of the digital model. Bottom Left: The physical model during scanning with a visible reference point. Bottom Right: The digital model with overlaid triangles.



Figure 4: Juglet of Red Polished Ware. Top: The raw scans with the artificial reference points visible. Middle: Two views of the digital model. Bottom Left: The physical model during scanning with a visible reference point. Bottom Right: The digital model with overlaid triangles.



Figure 5: Juglet of the Black Polished Ware. Top: The raw scans with the artificial reference points visible. Middle: Two views of the digital model. Bottom Left: The physical model during scanning with a visible reference point. Bottom Right: The digital model with overlaid triangles.



Figure 6: Left the digital model of the juglet of the red polished ware with the closed rings and the distorted rim. Middle the physical model. Right the digital model with the rings restored and slightly improved rim.



Figure 7: Two artefacts with the number of faces reduced to 25%. Loss of quality is evident.

## 5. DISCUSSION

3D digitization offers several advantages including spare of time related with the manual design, more accuracy, repeatable procedure, non-destructive method as no physical contact with the object is required, easy to store, retrieve and render the digital object.

In addition, being able to process digitally archaeological artefacts offers opportunities that were impossible before. Some of these are reconstruction of broken objects by digital assembly of their fragments, partial restoration of the object using various possible scenarios, easier to study the object, easier to compare an object with other objects, replication of the object using 3D printers, creative presentation of one or more objects using storytelling techniques, building a 3D interactive virtual museum, keep the object safe in an appropriate climate avoiding movements and igro-thermal shocks and use the replica.

In contrast, with 3D digitization several challenges and/or problems emerge. For instance, artificial reference points must be used to enable correct alignment. If we are not careful we might corrupt the artefact or not capture important characteristics that might be occluded by the reference points.

Also, digitization fails to document eye-visible details such as shallow lines. In cases that the artifact has small rings (artefact Δ0413) the holes disappear and must be recreated during post-processing. Another issue is that many scans must be done per artefact that must later be aligned. With more scans, more geometrical inaccuracies may be generated.

The 3D scanner Konica-Minolta VI-9i can not provide high resolution texture (resolution is 640x480) with correct coloring. In addition, photo-realistic rendering is extremely hard to achieve, especially due to bad texture and lack of knowledge of the artefact's physicochemical material properties.

## 6. CONCLUSION AND FUTURE WORK

In this paper we have presented preliminary work for a project aiming at digitization of at least 100 archaeological artefacts, development of a quality assurance protocol, a virtual restoration tool and a virtual museum tool to provide an interactive demonstration of the archaeological artefacts.

We analysed extensively the challenges and opportunities regarding digitization as well as the constraints of current technology. A major challenge is the implementation of a quality assurance protocol with feedback and major opportunities include a virtual restoration tool, virtual museum providing a natural experience and tools to aid digital study of the artefacts by the archaeologists.

Future work of the project includes addressing both the challenges and opportunities, discussed in the paper, with close collaboration of the archaeologists.

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## 3D DIGITAL DOCUMENTATION FOR THE RESTORATION OF CULTURAL HERITAGE. THE EXPERIENCE OF THE OLD CITY OF ALEPPO REHABILITATION PROJECT

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**KEY WORDS:** Tridimensional survey, Laser scanning, Photogrammetry

### ABSTRACT:

The Old City of Aleppo Rehabilitation Project is being carried out by the Directorate of the Old City in collaboration with the German Technical Cooperation GTZ. The main objective of this project is the preservation and development of the Old City (UNESCO World Cultural Heritage Site from 1986) after the destruction of a large area in this district of the city by the Master Plans from the early 1950s to the late 1970s. In this context, the restoration of more than 240 classified historical monuments will be carried out. One of them is the Antioch Gate (Bab Antakya) on the perimetral wall around the Old City. In order to obtain the necessary documentation for the restoration project different technologies were used: 3D laser scanning, total stations and digital and analytical photogrammetry. This paper shows the results obtained using the different methods abovementioned, its advantages and drawbacks will be weighed against each other.

### 1. INTRODUCTION

The old city of Aleppo is one of the oldest inhabited cities in the world. It was declared Cultural Heritage Site by the Unesco in 1986 due to its particular characteristics and as a protection measure after part of the city's fabric and historical buildings were demolished by the Master Plan for remodeling the city.

Since the beginning of the 90s, buildings, monuments, squares and the city's infrastructure have been restored and renovated. This required joint efforts from municipal and state authorities, and benefited from international support. Thus in 1992 the German government and the Arab Republic of Syria started to work together to improve the urban management capabilities of the municipality of Aleppo. The restoration of the former city of Aleppo was the ultimate objective of the project (Busquets, 2005).

In this context, and in collaboration with the project RehabiMed (Rehabilitation of the Traditional Mediterranean Architecture), and several groups of the city of Aleppo, the three-dimensional survey of the Antioch gate was made with a terrestrial laser scanner system of Riegl and analogical and digital photogrammetric methods. The result of the survey will be the first step towards the rehabilitation project of the gate.

#### 1.1 The city of Aleppo

The city of Aleppo is located at the crossroads of caravan routes, between the Mediterranean and the plains of Mesopotamia, between the Orontes and Euphrates rivers, 350km north of Damascus.

It is one of the oldest cities with a continued population documented (the first settlement dating of 5000 years ago). Its urban fabric is a result of having been under the control of the most diverse cultures, with a street structure in the souk and near the citadel that persists from the Hellenistic and Byzantine period, and buildings dating back to the Islamic period, which

preceded the Mongolian and eventually the Ottoman domination. Much of the urban fabric and several mosques belong to that period. After the fall of the Ottoman empire, Aleppo was under the French colonial administration before it became part of the Arab Republic of Syria.

The declaration of the Old City of Aleppo site as a World Heritage Site by Unesco includes the historic center, surrounded by a wall with seven gates, the old north, north-east and east districts, and several monuments isolated further away from the historic center. The gate that used to open onto the road of Antioch was the subject of the survey.

The Antioch gate is made up two towers, figure 1: the left tower is attached to the wall built by the French, while the right tower borders on a shed which is used to store construction materials. The corridor with access to the souk is in the latter tower. Off its inner walls there are several rooms which are used as small shops and a mosque.

The interior of the left tower is divided into several spaces that communicate with each other by means of a corridor, the back wall of it runs against the ancient perimetral wall of the city. These spaces are currently used as a warehouse for itinerant traders.



Figure 1: Bab Antakya photograph

On the passage and the left tower there are buildings used as private homes. Their interior walls are supported in many cases against the external wall of the towers.

Off the walls of the two towers were several houses and shops that were demolished before making the works that provided the metric documentation of the gate. The outline of these buildings can easily be seen, particularly on the stone wall outside the right tower.

## 2. INSTRUMENTS AND METHODOLOGIES

Because the data capture had to be done in a very limited period of time—only five days—and given the complexity involved in measuring the old building—because of the existence of multiple rooms—and the difficulty of working in the area (it is an area of great transit of people and goods), it would be necessary to use different techniques in order to ensure that all necessary information was collected. That is the reason why both methods, laser scanning and stereo-photogrammetry, were used to complement each other (Wend, 2007). In both cases, support of topographical work to establish a reference coordinate system and to measure control points was needed (Moons, 1997).

Photogrammetry has been traditionally due to its characteristics (Yilmaz et al., 2007; Scherer, 2002) the method used for the cultural heritage documentation ([www.icomos.org](http://www.icomos.org)).

Before the topographic survey, houses that stood against the wall were demolished. Then the rubble and other existing elements in the area had to be cleared.

The methods and tools used are described below.

### 2.1 Instruments

The laser scanner model Z420i Riegl (Riegl, 2008) was used: it has a wide range of visual field, i.e. from 0 to 360° horizontal movement, from 0 to 80° vertically, and a distance range from 2m to 800m. The resolution of the grid can be fixed at 0.0025° and 0.002 for horizontal and vertical respectively. The method of measurement used by the system is the time of flight, TOF (Ullrich, 2001; Stephan, 2002).

A calibrated high-resolution digital camera Nikon D100 (6 megapixel) is mounted on the sensor, figure 2. This camera, known its position regarding the capture system, makes it possible to allocate to each point of the cloud swept its color and texture automatically.

In order to establish a reference system, as well as to take control points and targets, a total station non-prism model TCR705 Leica was employed, with an appreciation of 10cc and a distance accuracy of  $\pm (3\text{mm} + 3\text{ppm})$ , being the measurement range from 2m to 60m.



Figure 2: Laser scanning of the wall in vertical position and capture of the target coordinates

For photogrammetric work two types of camera were used:

- Rollei 6006semi-metric film (6x6cm), réseau plaque with 121 cross, with focal length 40.49mm and 80.15mm. Distortions are controlled for both focals up to 50 $\mu\text{m}$  and 200  $\mu\text{m}$  for f1 and f2 respectively.
- Digital Nikon D200, it allows to work with several focal lengths.

### 2.2 Preliminary work

Before starting the works, the reconnaissance of the area was performed in order to plan the tasks. The topographic network was established and the position of the targets was studied. They were homogeneously laid out following a pattern similar to the points of Gruber in a photogrammetric model. The reflective targets were so that in each point cloud there would be a minimum of 4 whenever it was possible.

Once the area was reconnoitred, the position of the points where the photographic coverage and laser scanning measures were taken from was decided. In each position three scans were performed (partial scan and complete in horizontal and vertical). For the laser scanning capture both the resolution of the grid and the quantity of photos should be taken with mounted calibrated digital camera in order to give colour to the points during the laboratory works.

### 2.3 Topographic work

The first job was setting up a network observed by the Moinot topographical method. It was made up of 14 stations located at different heights, so that the complete survey of the Antioch gate could be performed. Once the coordinates of the network were adjusted by the least square method, the coordinates of the targets were measured. These would be used later for the orientation of the photos in the photogrammetric process, in the rectification of the photos and to georeferencing the laser scans from different viewpoints to the reference coordinate system. Moreover the coordinates of several singular points identifiable on the images, they will be control points for subsequent work.

Further points were taken in the various planes of wall to define the perimeters, details and depths. The accuracy of the coordinates is  $\pm 1\text{cm}$  ( $1\sigma$ ).

### 2.4 Photogrammetric works

The photographic coverage has an average scale of 1/150 to obtain the rectified photos and orto 1/50. The photos were taken

twice, first with the semi-metric camera Rollei with focal length 80 mm, except in the central part between the two towers, where due to the distance to the object the focal length used was 40 mm. The film used was a Kodak color photographic emulsion sensitivity ISO 100. There is an overlap between photographs of at least 60 %. The photographic coverage was repeated with the digital camera Nikon D200 model at maximum resolution.

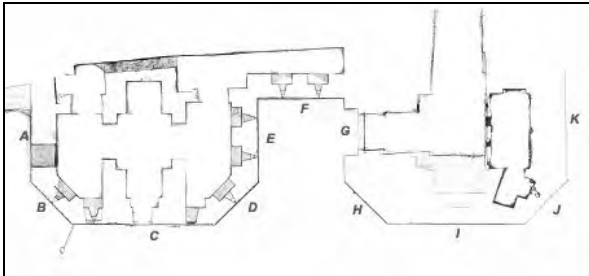


Figure 3: Facades layout

The photographs of detail of the existing inscriptions on the facades E, F and G zone between the two towers, figure 3, were taken with the same camera.

The photogrammetric work has the aim of obtaining the front view of the towers and the area between them.

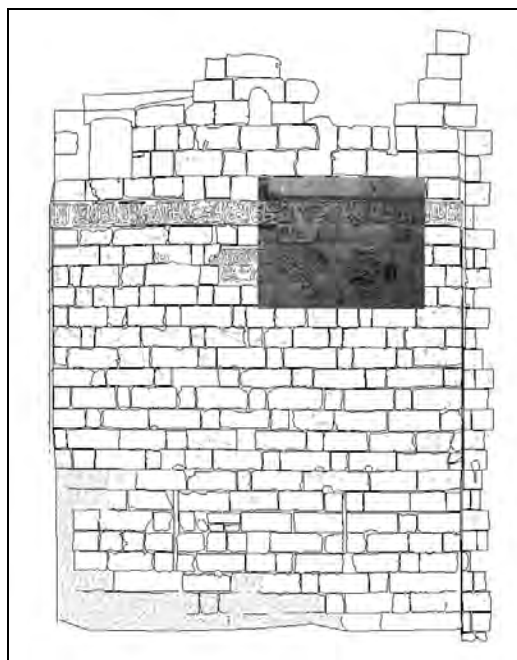


Figure 4: Vectorial model and detail of the orto

The photos taken with the Rollei were scanned at a resolution of 2000ppi. The software SOCET SET © by BAE Systems was used in the orientation, generation of the digital terrain models and orthoprojection processes, after the 3D vectorization of the ashlar, inscriptions,... on the facades were performed, figure 4. In the areas where orthophotograph does not provide the necessary quality, because of the image displacement due to a wrong digital terrain model (Buill et al., 2007), the differential

rectification of photographs has been used, figure 5. For this process the measurement of the control points has been need.

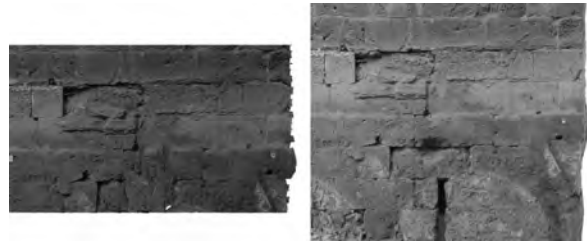


Figure 5: a) Error on the orto due to the displacements for a wrong DTM, b) Orto corrected by the DTM effects

## 2.5 Laser scanning works

Using the laser scanner sensor, the complete survey of the gate (outside the wall, outside and interior of the towers) was performed.

This required approximately 60 scans since a general scanning was made at each position which allowed the subsequent combination of clouds with a resolution mesh 3.5cm to 10m, and another vertical resolution mesh 1.5cm by 1.5cm to 10m. These scans were completed, if necessary, with scans performed with a horizontal positioning of the head longitudinal and transverse laser positions. The distance between the scanner head Riegl and the models was in a range from 2 to 50m, although data of the environment were obtained at distances much higher. The scan resolution was 1-2cm at the average distance of work, and 10cm in the case of general clouds.



Figure 6: Laser scanning model

Sometimes laser intensity returned by the object, if IR wavelengths range are used, can be useful, especially in dark areas where the photographic capture is invalid. In this way the object can be shown through the captured points, giving them a value of gray depending on the signal received. In the case of study the maximum value of gray levels to be assigned to the reflectivity is  $2^8$  or 256-level which is sufficient for most cases. In other cases it may be necessary to expand the number of tones, so a sensor capable of increasing to 512, 1024 or more, the number of grey values is necessary, an example is Faro LS with 512 levels,  $2^9$ . In this way a change of material can be detected, figure 7.

Another application is to treat information reflectivity along with the color of the camera and treat this information in conjunction with remote sensing tools.

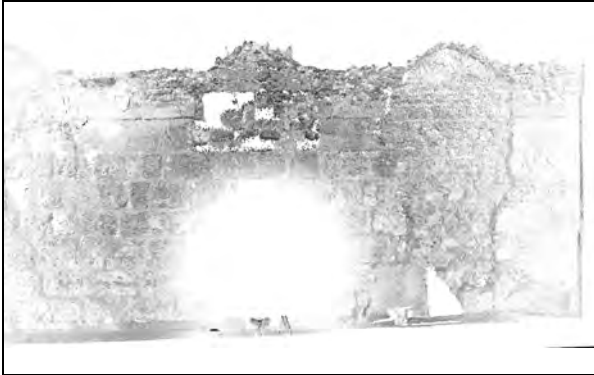


Figure 7: Interior wall represented by intensity

### 3. DATA PROCESS

After the field work, one of the first tasks is to assign the color automatically to every scanned point using RISCAN-Pro v1.2 .1b17 software of Riegl. This process is possible because the camera takes the photos from the same position where the cloud of points was measured and the distance between the axis of camera and laser sensor is known.

Before the clouds geo-referencing and merge it is necessary to filter and clean the clouds, removing all those points outside the object of study, in this case people, cars, furniture, cobwebs, etc.

In order to align the cloud points, at least four targets and points, whose coordinates were known by topography, were identified on the cloud points. These points were supplemented with the reflective targets which are automatically localized by the laser scanning data management software. Once positions of the control points were recognized, the transformation parameters between the system of coordinates for each scan and that defined by the topography were calculated. The accuracy obtained at the outset was about 3cm.

This process was very difficult in the case of clouds taken inside the towers, figure 8, because of the lack of light at the time of making the data capture, which made it difficult to identify the targets. In this case a greater number of points of detail such as boot arches, ashlar corners, corners of walls, etc. had to be used.

Later, once all the clouds were geo-referencing in the same reference system, a more accurate alignment was performed, using the matching surface by least square adjustment, improving the global accuracy (Gruen & Akca, 2005; Wolf & Ghilani, 1998). The result was a complete model of the gate, interior and exterior, and part of the annexed French wall.

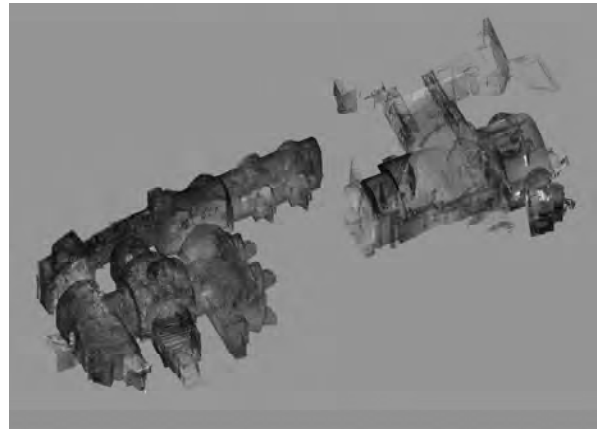


Figure 8: Interior of the towers

Since the buildings on the left tower are private houses, there was no access to them and no data could be retrieved of the cover that would have allowed to determine the gate completely.

The project does not take into account the possibility of generating a model with a mesh or surface, since only metric information was necessary to establish the constructive process for the restoration of the gate. However the reconstruction of a triangulated surface from the sampled point clouds are being carried out in the present, besides the least square adjustment of the quadratic surfaces to the vaults.

### 4. RESULTS AND CONCLUSIONS

The first results obtained were the ortos and rectified photos of all the facades. Together with the restitution of the photogrammetric models, they allowed to draw the lines of the facades showing the ashlar, as well as the existing pathologies. It should be borne in mind that in some of the areas and due to the deterioration of the stone, any decision on the delimitation of the outline of each ashlar, fissure, etc., was subject to the operator's discretion. So, it was decided that in those areas where a reliable identification was not possible, the drawing would be replaced by a hatch.

On the other side, the three-dimensional digital model was obtained from the cloud of points of the towers, interior and exterior, the corridor and the annexed wall. The clouds merger, once geo-referenced, allows to obtain the three-dimensional model and thus provides a wealth of information. The model accuracy is 2cm. Moreover both horizontal and vertical sections can be obtained from the same cloud of points.

Data about the width of walls, ceilings, as well as problems of collapse in the roof vaults of the rooms inside the left tower can be extracted very easily with the appropriate software.

Besides, the fact of having this type of information allows us to obtain accurate architectural sections with less time and less costs.

In this case, as a complement to horizontal maps obtained by topography, horizontal sections were performed at various altitudes and various vertical sections, figure 9, which will make it possible to analyse the design of original wall behind the door

and the French wall, the thickness of the walls between different rooms, the geometry of the vaults,...

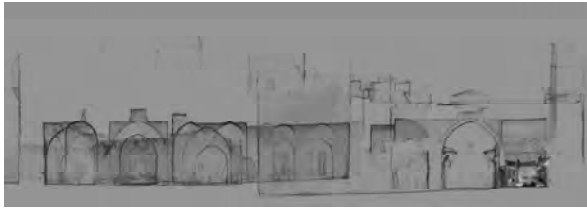


Figure 9: Section

For these reasons, it can be said that work with laser scanner has changed the concept of topographic survey. So far, before capturing any data, it was necessary to have a very clear idea of what sections were fundamental, since those were the only sections that would be obtained in the field. The availability of three-dimensional information allows us to obtain as many sections as necessary for the same cost of fieldwork, simply by changing the viewpoint of the cut to obtain other information, a fact that becomes more relevant when the laboratory work will be developed thousands of miles away from the measured object.

The possibility of working with a three-dimensional model makes it possible to extract graphic data that help to understand the space in which we are working and the spatial relationships that exist among different elements that make up architectural groups. This makes it easier to analyse the processes and methodologies that will be carried out in the restoration of architectural heritage.

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# RECORDING AND DOCUMENTATION OF ARCHAEOLOGICAL AND ARCHITECTURAL FRAGMENTS USING AUTOMATED STEREO PHOTOGRAMMETRY

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**KEY WORDS:** Stereo Photogrammetry, Image Matching, Ortho images, 3D-Modelling, Building Archaeology, digital SLR

## ABSTRACT:

Research in building history is based on detailed analysis of building remains. Therefore, archaeological finds and building fragments are measured in high detail and in a classical approach documented in plan, elevation and section drawings. These drawings are the basis for all further research, and finally means of argumentation and presentation in reconstruction drawings. All scientific progress is based on an intensive hands-on work with the object. However, this traditional manual survey needs more and more time as geometrical complexity of the object increases. Consequently there is a long list of attempts to reduce this time by technological means. All of these technologies need to be compared in respect of accuracy, time and costs. For example scanning is used in a relatively small number of projects, due to high costs to date and very specific fields of application of each scanner type. Digital stereo photogrammetry offers efficient and flexible surveying of building fragments and finds. The photos can be taken by the user through a calibrated but otherwise usual digital single lens reflex camera on a stereo-bar. Relative orientation of the photos is achieved by automatic image correlation in image pyramids in a software solution. In a batch of two to four oriented images automatic image matching generates 3D object points in a high density. The resulting point cloud is the basis for the deduction of the final result, which can be ortho image projections, sections, or textured 3D models of the original object.

The application of digital photogrammetry in building history and archaeology will be presented in a selection of recent projects. Furthermore a prospect of future development and improvements will be presented as a result of practical tests and experience with this technique.

## 1. INTRODUCTION

Building archaeology is a historical science that tries to retrieve information about architecture, society, technology, and most other aspects of the cultures of past times. As opposed to other historical sciences building archaeology is based on the analysis of architectural remains as its primary source of information. For this reason the survey and complete documentation of the architectural remains is vital for the following analysis and scientific work.

The classical survey comprises hand drawings to scale supplemented by photos, descriptions and catalogues as a systematic compilation of these different pieces of information. The drawings encompass floorplans, elevations, sections of a complete building as well as of technical or ornamentation details. That is why scales can vary greatly, from 1:1 in detail drawings to 1:100 or larger in drawings of one or more buildings. The level of accuracy in these representations is limited by the scale of the final drawing. At the same time the required level of accuracy for the survey is only determined by the scientific goal it is made for. According to this, sketches with supplementing measures will be fine for most typological comparisons, whereas even reflectorless tachometry may be hardly sufficient for work on the curvature of a Greek temple. Consequently the appropriate level of accuracy is defined for each particular project.

The object of survey and documentation is to collect all relevant data to answer the actual scientific objective. This high density of information requires a lot of time to collect.

The time needed to complete the hand-drawings increases disproportionately for spatially complex geometries. Drawing badly preserved fragments possibly needs more time than drawing the best preserved examples.

The technical development to reduce the time spent and enhance accuracy in surveys started long before Albrecht Meydenbauer and will continue for a long time coming. Today it is near possible to do virtual 1:1 representations by modern scanning technologies (Akca et al, 2006), and we can discuss the “objectiveness” of documentation (Riedel, Bauer, 2008).

However for or the best part of work in building archaeology the maximum accuracy of surveying techniques is not a limiting factor any more. More crucial factors would be expense of time and money and, more important, usability.

For acquisition of 3D data procedures using digital amateur cameras proved to be an alternative to recent scanning technology (e.g. Boochs et al, 2007). In the following stereophotogrammetry shall be presented as a time- and cost efficient technique for the survey of building fragments and archaeological finds, as two possible fields of application. It is designed to enable the end user to perform a survey that meets the requirements using only a calibrated, but otherwise standard, Digital SLR camera.

## 2. PHOTOGRAMMETRIC RECORDING

In the fields of archaeology, building archaeology and preservation of historical monuments photogrammetric techniques are frequently used for documentation and data

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acquisition, as numerous papers at the CIPA symposia of the last years show (e.g. CIPA, 2005 and CIPA 2007). Photogrammetric techniques offer a big advantage over discrete measuring techniques, like hand measurements, tacheometry and laser scanning, in continuous covering of the objects surface in a high resolution at the time of the exposure.

Photogrammetry offers high-resolution documentation of the surfaces at the given time of exposure which is largely free of interpretation. Thus it can be understood as a most objective method of data acquisition. Given the appropriate means of storage photos can be used as original measured data for photogrammetric evaluation at any later date.

Image rectification of planar object areas is a common technique for 2D documentation since application oriented software is an established product, whereas advanced photogrammetric methods are rarely used by the end user due to their complexity.

## 2.1 Standard stereo configuration

Using stereophotogrammetry it is possible to document non-planar objects and free-form surfaces three-dimensionally. The process of evaluation can be split from data acquisition and postponed to a later date. During stereo evaluation the user is offered a three dimensional spatial representation through which can analyse the actual state, quality of finish, and depth differentiation of the surface. The technology introduced here will enable the end user to perform 3D documentation and evaluation of building fragments as well as archaeological finds on the basis of stereoscopic images. Starting in the beginning of the 20<sup>th</sup> century the know-how of aerial stereophotogrammetric evaluation has been used to develop special techniques and instruments for terrestrial use (Szangolies, 1986).



Figure 1: Using just one digital SLR camera on a calibrated base bar.

According to classic stereometric cameras with fixed calibrated base distances a simple base-bar can be used to provide a calibrated distance for two standard cameras (Figure 1). Making use of such a base bar it is possible to ensure an image configuration that complies with the advanced normal case of stereophotogrammetry. By purposefully keeping roughly parallel viewing directions it is still possible to achieve stereoscopic perception in analysis and presentation of the object. Additionally this configuration facilitates the automated correlation of homologous image points in image orientation and evaluation.

Through the known basis of the image configuration the model system of a relative orientation can be scaled to the object space without further reference information. This allows for time

efficient documentation of small objects like building fragments and archaeological finds on site. There is no need for further reference points, and still the objects can be evaluated to scale later. Alternatively objects with known 3D coordinates can be inserted to the object space which means a calibrated base-bar can be omitted. This way one or more stereo models can be assembled in a consistent object coordinate system through absolute orientation.

For image recording digital single lens reflex cameras with fixed-focus lenses are used that have been calibrated for specific focus settings. For the requirements of photogrammetry this camera type combines high sensor resolution with good lens quality and sufficient geometrical accuracy (Läbe, Förstner, 2004). As Läbe and Förstner show the use of digital zoom cameras would generally be possible as well, but under the prerequisite of higher effort. In this case unstable interior orientation and lens distortion changing with different focal lengths require higher effort for simultaneous determination of the interior camera parameters in image acquisition as well as in image orientation.

## 2.2 Extended four camera configuration

In classical stereo configuration with only two images the process of automatic image correlation can result in wrong correlations and object points due to possible ambiguities along the epipolar band (Maas, 1997). Maas proposes to extend the stereo configuration to three or more camera positions, which reduces the probability of wrong correlations calculating the intersection of epipolar lines of two or more images.

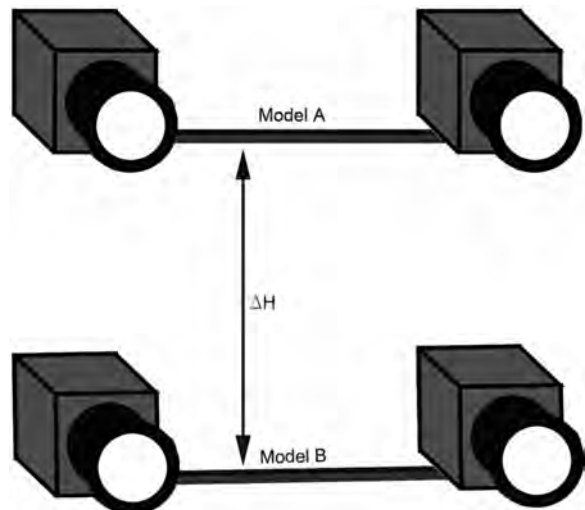


Figure 2: Four camera configuration by vertical shift of Model A about  $\Delta H$

The configuration described in 2.1 can be easily extended to four camera positions by moving the basis (Model A) vertically (Figure 2). Basis A and basis B should be kept approximately parallel in this process to ensure automatic image correlation over all four images. During image orientation the calibrated base distances of two models allow for an additional check of the orientation. As an extra the additional image pair (model B) can be used to add information on areas not covered in model A, and thus help to avoid bad spots in the 3D Model.

### 2.3 Combination of overlapping models

For the entire coverage of building fragments multiple stereo models need to be linked. After relative orientation of single image pairs neighbouring models can be transformed into one consistent coordinate system via identical object points. For this it is useful to insert 3D tie points into the object space that can be identified clearly and measured precisely from different positions. The use of white tetrahedrons as tie points for multiple stereo models is shown in Figure 3. The determination of these 3D tie points can be automated by extracting edges of a tetrahedron and calculating their intersection point.

A combined orientation of all images in a bundle block adjustment would possibly be a natural choice from the perspective of photogrammetry. Still for development of a user-oriented system the step-by-step concept introduced here has been chosen deliberately.



Figure 3: Using white tetrahedra as 3D targets for the linkage of several stereo models

### 3. AUTOMATED STEREO EVALUATION

Due to the substantial similarities of stereoscopic image pairs, manual stereophotogrammetric evaluation can be supplemented or substituted by automated image correlation. First an automated depth measuring function was implemented for easy positioning of the floating mark on the object surface that works according to the Vertical Line Locus procedure (Cogan & Hunter, 1984). For comparison of image patches the normalized cross-correlation coefficient (see i.a. Piechel, 1991) is used which provides the position of best correlation in one-pixel accuracy. Sub-pixel localisation is achieved in a second step via least squares matching (LSM, see i.a. Ackermann, 1984, Förstner, 1982). LSM is used to determine the parameters for geometric and radiometric transformation of two image patches by an iterative calculation of grey level differences between reference and search matrix. It offers an improved accuracy especially for images with larger perspective differences. Moreover the adjustment calculation of LSM provides statistical estimation of the obtained inner accuracy.

A time efficient non-iterative sub-pixel localisation can be achieved via paraboloid-interpolation (Rodehorst, 2004). Taking the maximum of the cross-correlation as a starting point and using the correlation coefficient of eight neighbouring positions a biquadratic paraboloid can be calculated. The

maximum of which provides the sub-pixel difference to the position of the one-pixel correlation maximum.

#### 3.1 Image orientation

The first step of relative orientation is the calculation of orientation parameters in a model system through homologous image rays in both images. The measuring of homologous image points in two or more images for relative orientation is facilitated substantially by the integrated correlation techniques. The user does not have to insert specially marked tie points into the object space, but can rely on natural points for an ideal point distribution. For manual evaluation image points with sufficient texture information will be defined in one image. The search area for the corresponding image points has to be specified by the user. After the first calculation of relative orientation parameters, the search area for the correlation process can be automatically limited to the corresponding epipolar band.



Figure 4: Homologous image points, extracted using Förstner-Operator, followed by cross-correlation

By extracting relevant point features in both images using an interest operator determination of image points can be automated completely. For this the Förstner-Operator (Förstner, 1986) has proved to be very reliable. Afterwards identical interest points are correlated in sub-pixel accuracy via image correlation (Figure 4).

For orientation of extended four-camera-models first identical image points are measured either manually or automatically in all four images. Separated relative orientation for both stereo models provide approximate parameters for a consecutive bundle block adjustment. For this adjustment the base distances are used as known parameters.



### 3.2 Dense surface and profile measurement

On the basis of known parameters for interior and outer orientation in the next step 3D coordinates of image points in the object space can be calculated via forward intersection. The image matching can start in single or multiple points and expand to neighbouring image areas through a special algorithm. In the end the automated documentation of object surfaces results in a dense 3D point cloud (Figure 5).

The user can define the increment for expansion and the size of the search area for matching depending on image resolution and surface structure of the object as well as the image area that shall be evaluated.

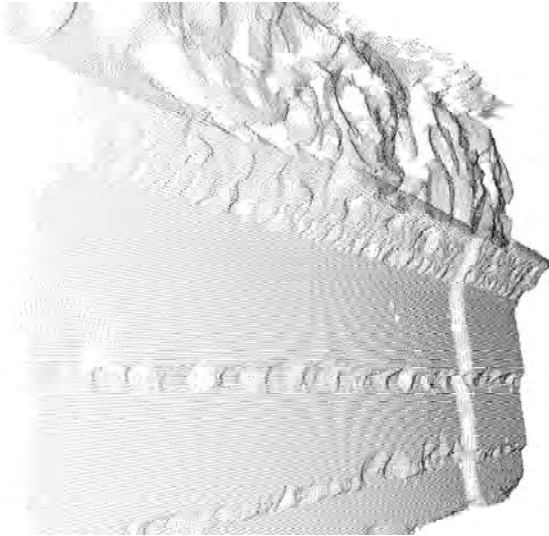


Figure 5: 3D point cloud generated with image matching

For evaluation of horizontal and vertical profiles a profile line for the automated measurement is defined in an aligned perpendicular coordinate system. The evaluation can be generated similar to surface determination using expansion algorithms for image matching. The resulting dense profile of 3D points can be exported to a DXF file for use in any CAD system. Thus the profiles can be combined with other measurements for a virtual reconstruction (Figure 6).

## 4. RESULTS OF STEREO EVALUATION

The primary results of automated stereo evaluation are dense point clouds of the object surface similar to those of scanning techniques. Extracting the 3D information out of images automated stereo photogrammetry allows for assigning colour information to every point directly. This “textured” point cloud gives a very illustrative first impression of the digital 3D model.



Figure 6: Anaglyph image with automated measured horizontal and vertical profile lines

### 4.1 Surface triangulation and texture mapping

Digital surface models can be generated from point clouds using the Ball Pivoting Algorithm (Bernardini et al, 1999) (Figure 7). This algorithm can be compared to a virtual sphere rolling over the point cloud surface. The radius of this sphere needs to be large enough so the sphere will not “fall through” the point cloud surface. Starting from a position resting on three points the sphere is pivoted around two points to find a new third one. This procedure is repeated until there are no new triangles of three points to find. Because of the uneven spatial distribution of points in a point cloud one radius is not enough to ensure the ball pivoting algorithm can triangulate a complete point cloud. The solution to this problem was found in triangulation with multiple radii (Vetter, 2005).

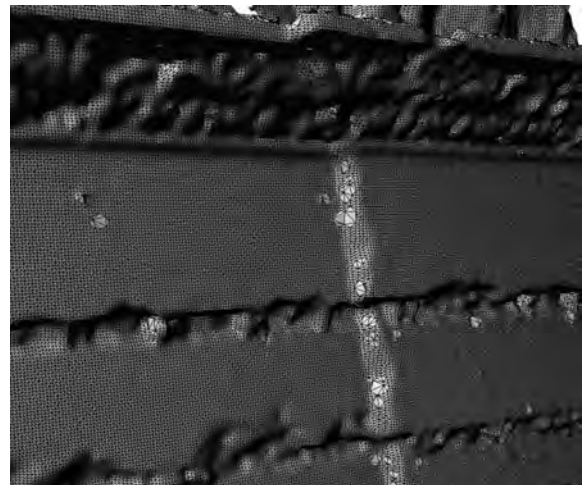


Figure 7: Result of surface triangulation using Ball-Pivoting-Algorithm

For the final textured 3D model the points of each triangle are projected into the relevant images via the collinearity equations (Figure 8). The angle between normal vector of the triangle and the image ray determines which image colour information is taken from. Finally the image coordinates for every triangle are saved as texture coordinates and can be exported with the 3D model as STL or VRML files.



Figure 8: Final textured 3D model

#### 4.2 Ortho image generation

For work on architecture and building fragments two-dimensional projections like elevations still are the most important means of documentation. The survey is normally done in hand measurement. Only objects that are difficult to reach, that show a complex three-dimensional structure, or especially those that are so badly preserved that large parts of the object show an amorphous surface take a long time to survey. As geometrical support for drawn documentation ortho images can help to save the best part of this time. After setting scale and resolution of the ortho image a projection plane needs to be defined using points or planes of the model itself. For every point of the image the piercing point, that is located orthogonal to the projection plane on the model, is determined. The coordinates in the stereo-images are calculated through collinearity equations and the colour information for the ortho image is determined via suitable interpolation (Figure 9). The generated images can be imported to CAD systems, or printed out as scaled reference for hand drawings.



Figure 9: ortho image (blank regions show occluded object parts or holes in the 3D model)

#### 5. FURTHER AREAS OF APPLICATION

Collaboration with building historians and archaeologists has shown further areas of application for stereoscopic object documentation in archaeological research projects. For example this technique can be used for documentation of finds and sherds. Due to the smaller size of these objects base distance and object distance need to be reduced. At the same time the reduced size meant it was possible to develop a frame with defined pass-points marked up to hold the objects (Figure 10).

Using this installation, stereo models of both sides of an object can be related directly. For the archaeological analysis of sherds high resolution 3D models and especially profiles are needed for classification (Figure 11).

Another area of application is documentation of archaeological sections and soundings. Automated stereo photogrammetry is a time efficient and easy to apply technique to cover layers of different colour and objects in archaeological profiles. Again ortho images are result most asked as they can be used as a base for hand drawings.

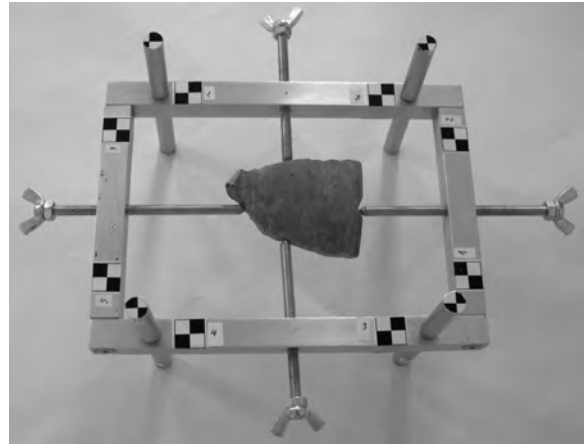


Figure 10: Calibrated frame for the stereo-photogrammetric registration of upper and lower surface of sherds



Figure 11: Textured 3D model and belonging profile line

#### 6. CRITICAL REVIEW AND PROSPECTS

At the present stage it is proven the concept of automated stereo photogrammetry is suitable for a number of different applications in archaeology and building history (see Boochs et al, 2007 or commercial software PhotoModeler-Scanner by Eos Systems Inc.). Using digital SLR cameras for stereoscopic image acquisition a light weight and cost efficient surveying system has been developed that offers a high level of flexibility. There is no need for special lighting of the object. Batteries inside the cameras allow for fieldwork independent of additional electricity.

The automated functions presented here facilitate accurate and comprehensive documentation that needs little time and hardware. The level of detail and accuracy depends on the

image configuration and the cameras used. The quality of the resulting point clouds is on par with scanning technologies that necessitate much higher expenses. At the same time evaluation of high-resolution images offers additional information on surface quality on top of geometrical data. These advantages over other scanning technologies recommend stereo photogrammetry for many different applications in archaeology and building archaeology.

At the same time an extensive series of tests has shown potential for further development. Automated stereo photogrammetry is based on the correlation of two image patches in both images. This is possible only if there is an irregular surface structure to compare. Surfaces without, or with a regular structure cannot be covered with this technique as well as gleaming surfaces. In those cases auxiliary measures like speckle texture projection or temporary surface coating are needed.

In a standard workflow evaluation of stereo models will be separate from data acquisition. Thus a check of the results will be possible only after fieldwork. The time needed for generating a point cloud depends on the chosen density of image points, image resolution and scale of the image. At present calculation of one point cloud from one image pair typically takes 1–2 hours using recent hardware. An implementation of batch handling allows to go through a swift procedure of set up before starting the user-independent evaluation process for more than one model at a time. Further work steps to produce 3D models or ortho images are identical in time and effort to processing of point clouds of other scanning techniques.

As a result of the technical approach edges are smoothed or rounded depending on the size of the search matrix in the matching process. Future work will focus on an implementation of automatic edge detection for 3D - modelling.

Linking multiple stereo models via interactively defined pass-points has been proven to be the part of the workflow that is most inflexible and complicated in handling. A better solution should be found in orientation of models using overlapping point clouds via surface matching (see i.a. Gruen & Akca, 2004). For this only the relative orientation of a stereo model is needed. The point clouds are generated independently in different model spaces and transformed into one object system later. This is achieved minimizing the point distances of overlapping areas of point clouds.

Another potential field for optimization is data acquisition on site. Major simplification of the process can be achieved through use of two calibrated cameras for synchronous recording of images. This would mean a serious saving in time as it affects different aspects of the workflow. As a one-camera system has to rely on a very stable basis there is need for a heavy Tripod, a double-camera system could possibly be operated without support. And further parts of the evaluation process could be automated like the identification of image pairs by the time taking the image. As a surplus accuracy would be further increased by the then fixed stereo configuration.

For the tests until now calibration of the cameras was limited to only a number of focus settings. This predefinition of available distances for image acquisition is highly impractical on site. The concept of orientation can be extended to simultaneously determining focal length and principle point using the known base distance. This is assuming constant distortion parameters, within the predefined limits of required accuracy for different focus settings. And finally the system is in a prototype stadium that shows a lot of potential for optimizing weight and handling. Quality and accuracy of the results in this technology depend on stereo configuration on site, and later on a number of parametrical settings during evaluation. This refers to orientation, and automated measuring as well as triangulation

and final production of ortho images. The layman user of the software has to rely on preset parameters in the software and cannot objectively evaluate quality of the result. At the same time the professional needs access to as many parameters as possible. To make the system an easy and reliable tool for the end-user the software part of it needs to be as self-explanatory as possible with an appropriate level of guidance that does not put off either professionals or first time users.

The functionalities of automated orientation and evaluation in stereoscopic image pairs have been developed in collaboration between focus GmbH Leipzig and the chair of surveying at University of Technology Cottbus. The software metigoStereo is being developed as a user-oriented tool in the field of architecture, building archaeology, archaeology and preservation.

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## THE LEGACY OF COLONIAL BUILDINGS IN KHULNA CITY - AN APPROACH TO DIGITAL DOCUMENTATION

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**KEY WORDS:** Digital documentation, Colonial buildings, Virtual reconstruction, Architectural Heritage.

### ABSTRACT:

Khulna city was established during the British colonial period as a sub divisional centre in 1842. The city is characterized by a number of colonial buildings scattered all over the city area. For the last hundreds of years these beautiful buildings with their distinct aesthetic value were acted as the source of inspiration of new development, as well as building city image. But, once these magnificent pieces of buildings enrich the beauty and glory of Khulna city are now facing severe pressure in keeping existence due to rapid urban development.

On the other hand, Department of Archaeology of Bangladesh is mostly interested on built-heritage of national interest and merely on colonial artefacts. The problems associated with such job is, it needs time, money and expertise. As it is the reality, that we are unable to preserve physically most of our valuable artefacts – digital preservation may be one potential solution. Keeping this fact in mind we have identified more than more than two hundreds potential colonial buildings and made an attempt to digitally document them. In first step by defining the exiting typology twenty buildings have been selected and documented in detail with CAD drawings and photographs. In second step, 3D rendered models of some artefacts have been developed. The study has found; excluding the initial investment the overall financial expenses is quite affordable. Author hopes this study can be used as an example for digitally preserve and documenting other colonial buildings in Bangladesh.

## 1. INTRODUCTION

### 1.1 Background

'Khulna' city was established during the British colonial period as a sub divisional centre in 1842. Khulna was declared as municipal town in 1884 and the next year Kolkata-Jessore railway was extended to Khulna. Railway station was setup in 1904, which was a major attribute for growth of Khulna (Ahmed 1984). Since then, the actual growth of the town became evident. This was expedited by development of communication with other parts of the province by rail and steamer services that were already established. River became the all-important route of transport for this coastal town, which enhanced the importance of riverfront as probable setting for the new buildings that followed afterwards. Parallel to the riverbank came up administrative and civil buildings, the characteristics of which are spacious setting and an image of prominence. In the inner area away from the river and parallel to the alignment of buildings a metal road (now called K.D.Gosh Road) was built. As the pressure mounted the building projects were carried out on the other side of this road. Eventually by the turn of the century, this whole area along the Lower Jessore Road became the administrative entity, the civil line of the British Raj (Mridha & Khan 2002).

On the other hand, artefacts of private nature are scattered all over the city area. For the last hundreds of years these beautiful buildings with their distinct aesthetic value were acted as the source of inspiration of new development, as well as building city image. But, once these magnificent pieces of buildings enrich the beauty and glory of Khulna city are now facing severe pressure of rapid urban development. Increases of need and rapid changes of use pattern are forcing new developments to invade these beautiful artefacts by completely replacing or altering the existing structures.



Figure 1: Marine Associate Building (demolished in 1999)



Figure 2: Nagar Bhaban (demolished in 2003)

Keeping this fact in mind we have identified more than more than two hundreds potential colonial buildings and made an attempt of digital-documentation through a low-cost approach. In first step by defining the exiting typology twenty buildings have been selected and documented in detail with CAD drawings and photographs. In second step, 3D rendered models of some artefacts have been developed. The study has found excluding the initial investment the overall financial expenses are quite affordable. The study aims to digitally preserve all those two hundreds buildings and publish them on web in future.

## 1.2 Objective

With limited manpower and resources the Department of Archaeology of Bangladesh (the authority that is responsible for conservation and documenting the past heritage) is mostly interested on built-heritage of national interest and merely on colonial buildings. Even these colonial buildings always attain public sympathy, the problems associated with such conservation job are, it needs time, money and expertise. Moreover it is also quite difficult for a government like Bangladesh to preserve such a big amount of artefacts scattered all over the country due to financial constrain. As it is the reality, that we are unable to preserve physically most of our valuable artefacts – digital preservation may be one potential solution. Keeping in mind the constrain of economic support and lack of expertise, this paper has tried to explore a cost effective solution for digitally preserve some colonial artefacts of Khulna city.

## 1.3 Methodology

Once a treasure is lost, so is lost the chance to study, analyze, or simply appreciate its impact on society. Through digital means, however, culturally significant sites can be documented and preserved by committing them to computer memory. Thus these wonders of the past can be enjoyed by present and future generations. Recently developed different techniques of ‘Digital documentation’ by means of 2D CAD drawing and 3D virtual model building technology through image-based modelling, 3D scanning, image-based rendering etc. have expanded the possibilities to virtually re-create antiquities and buildings. Digital tools and techniques now emerging from academic, government and industry labs offer new hope to the often painstakingly complex tasks of archaeology, surveying, historic research, conservation and education (Addison 2000). Even these technologies are widely accepted and practiced for virtual reproduction of built heritage and archaeological sites, such attempts have seldom tried in Bangladesh.

The study followed the following steps:

- In first step we have identified more than two hundred potential colonial buildings within Khulna city and studied their typology according to its patronization and use.
- In second step, existing technologies have been studied and the most available, effective and economic one is selected.
- To develop a comprehensive digital database, in third step twenty buildings have been selected from different typologies and an extensive photographic survey has conducted to ensure enough information to support 2D CAD drawings.
- In fourth step, digital drawings of selected buildings have been prepared through physical survey with photographic aid.

- Finally, 3D rendered models of some artefacts have been developed by using free software to understand the total procedure and related expenses of the digitalizing process.

## 2. DOCUMENTATION

### 2.1 Identifying building typologies

“With the British assuming political power in about 1757, architecture acquired a new dimension. Monuments with purely a European renaissance style appeared, initially in the British churches of Dhaka and few other outlying areas. Subsequently this style was applied to secular buildings, of which remains may still be seen in the Wiseghat locality in old Dhaka, and in Khulna district.” – Nazimuddin Ahmed (Ahmed, 1984).

Colonial artefacts in this region are basically product of two totally different cultures, the first the Indian, originally a mixture of Muslim and Hindu, the second the colonial form of a European and particularly British culture (Mridha & Khan 2002). The earlier, 19<sup>th</sup> century colonial urban settlement of Khulna was predominantly the civil lines. This was and largely still is an area of very low residential density, originally planned and built according to the values of the metropolitan society as interpreted by and for the use of a colonial culture. The residential section consists of European norms with spacious bungalows within large compounds. A large proportion of visual, symbolic or ceremonial space is incorporated in the layout. Roads designed for motorized elite rather than a pedestrian mass are broad and long; in contrast to the indigenous city. Climatic control is attained by extensive tree planting, illustrating a basic preference of the colonial culture.

After identifying more than two hundred buildings around the city, a broad category has been made based on the nature of their patron and use. The following figure-3 illustrates the typology of artefacts during the colonial period in Khulna city.

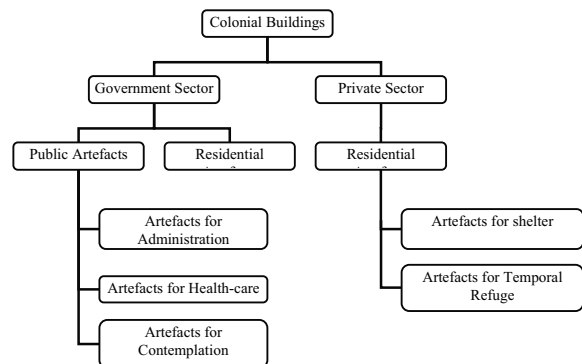


Figure 3: Artefacts typology according to patronization and use

This study has tried to select samples from each group to understand the complexity and nature of different artefacts. This typology also shows future possibility of academic research on these artefacts.

### 2.2 Technology

3D reconstruction or digital documentation of buildings has been an active research topic in computer vision as well as in Digital Photogrammetry for many years. Three dimensional computer graphics are increasingly necessary for the promotion of heritage as they offer alternative possibilities for different

kinds of tourist activity as well as research and learning opportunities (Koutsoudis et al. 2007). Extensive research in the fields of Photogrammetry, computer vision and computer graphics has lead to the development of commercial 3D scanning systems that allow effective high resolution digitization of heritage sites within short times. However, the quality of the final product is determined in many cases by the software that has been used to produce 3D model.

This study has attempted 3D reconstruction of some selected buildings without using any expensive equipment (e.g. commercial 3D range scanners based on techniques like triangulation, modulation or time of flight) or commercial content creation software. This study neither has attempted to present any novel approach. But by using educational version of CAD software provided by Khulna university (as a part of study fourth year design studio), this study has tried to explore the potentialities of the tools offered by the application in documenting and 3D modelling. Ordinary low resolution cameras were used for photo shooting and perspective correction was done manually. For rendering, freeware rendering application (Sketchup) was used to reduce the overall cost.

### 2.3 Photography and 2D digital documentation

In this project field survey followed by digital photographic survey was conducted to collect all necessary measurement and detailed photograph. During shooting photographs we have found enormous difficulties to capture the whole façade as well as different parts of the buildings clearly, due to the surrounding obstacles (trees, bushes, fences, electric poles with cables etc). As the project was low-budgeted most of the photograph was taken without the use of any special constructions (e.g: scaffolding, bases etc.). Furthermore we have also faced some most noticeable and common problems of barrel distortion and trapezoid disfigurement of the building facades due to perspective. Correction of geometric distortion and remove obstacles was found very time consuming and labour intensive.

Drawings were then prepared digitally with Auto CAD application with those measurements that had been found through field survey and aided by photographs. Some parts of the buildings e.g. column capital, railing was traced digitally through importing those photographs (in scale) into CAD program. Annex A, shows detail drawings and photographs of some selected buildings that have already been documented in first phase. Even the output may seems very similar to traditional drafting and CAD based drafting, but the benefit of manipulating, altering, copying of any part or whole drawing at anytime is quite impossible in first case. That means CAD based digital drawing has a wider range of flexibility in drawing manipulation.

### 2.4 3D documentation and visualization

The act of 3D computer graphics in preserving historical sites has grown significantly during the past decade. This expansion can be attributed to advances in scanning techniques, virtual reality, computing power, 3D modelling tools, presentation devices, and other related technologies, which have made it possible to virtually re-create antiquities and buildings (Andreoli et al. 2006; Rashid 2005). According to Rahaman (Rahaman & Sharma 2005) all the three ways (Geometric modelling, Photogrammetry and Laser scanning) of digital documentation has their own means and appropriateness in different contexts. However, he claims that Laser Scanning

technology provides the most accurate 3D virtual model but it is the most expensive techniques as it requires sophisticated machineries. On the other hand ‘Photogrammetry’ is the most one of the most ease technique but it needs relatively high resolution photographs from specific angles and expensive software. However, Geometric modelling technique is simpler but most laborious and time consuming.

Digital drawing (plan, elevation, sections etc.) which were prepared with AutoDesk’s ‘AutoCAD’ program in the last phase are used as the base material. 3D models were then developed with the same software, as the program offers a wide range of modelling techniques inbuilt within the ‘modelling’ section. Due to low-cost budget, the study has avoided industry famous commercial modelling and rendering packages like 3D Studio Max, Maya etc.

According to the complexity of the building’s plan and details, tools were preferred to work with ‘Polygonal’ modelling techniques and ‘Boolean’ solid modelling with editing option provided by AutoCAD®. It may also be possible to work with other software like 3D Studio Max or Maya etc. with techniques like: Nurb modeling or Patch modelling (Rahaman & Hossain 2007), for it’s wider possibility of mesh editing. But as our objective was to explore low-cost solution, we kept using single application package for whole process. Finally, the 3D models were imported to ‘Sketchup®’ software (freeware solution provided by Google®) for photorealistic rendering by applying material and light.

Figure 5, shows 3D rendered model of ‘Dakbanglow building’; located at the city centre at Khulna. Literally the word ‘Dakbanglow’ means ‘rest house’. When Khulna ‘Pauroshova’ was established in 1884; a demand of a rest-house was raised for the ‘Tax Collector’ of British Government from Calcutta, India. Due to meet this demand this building was made by ‘Zilla Porishod’ in 1885 (Bari 1979). We have chosen “*Geometric modelling techniques*” to build this 3D model by AutoCAD and rendered (texture, lighting, shadow etc.) with Sketchup.



Figure 4 : 2D detail CAD drawing of ‘Dakbanglow Building’

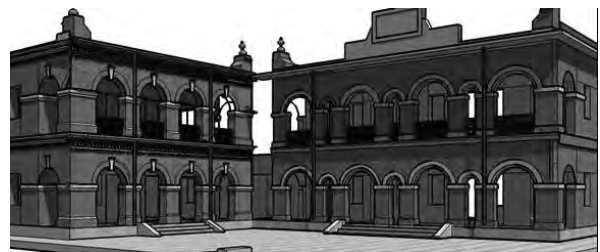


Figure 5 : 3D rendered model of ‘Dakbanglow Building’ with SketchUp.

### 3. SUMMERY OF EXPENSES

In this study we have digitally documented (both in 2D and 3D) some historical buildings in Khulna, Bangladesh. Different instrument and free or low-cost software were used for this purpose. Due to inadequate financial support this study followed the most inexpensive approach. From our observation the minimum requirement of labour and facilities that is required for any digital documenting can be explained from this following table:

Particulars of works	Remarks
(a) Survey & documentation	
Building survey	Required 2/3 days/case study, costs \$ 20~30/ building
Photography	Required digital camera, initial investment \$200~300.
(b) Digitalization	
Drawing Preparation (2D)	Labour cost for drafting \$10~20 /per drawing.  Required Software: AutoCAD (used educational version, supported by Architecture Discipline, Khulna University), commercial version costs 7000\$
Converting 2D from 3D	Labour cost approximate \$50~300. (Depends upon project complexity) Used Software: AutoCAD
Digital Rendering	Labour cost approximate \$50~200. (Depends upon project complexity)  Used Software: SketchUp ( <i>Google provides SketchUp as freeware</i> ).

Table 1. Required Labour and technical facilities for digital documentation.

### 4. DISCUSSION

Bangladesh is a land of indigenous development with rich architectural background. Hundreds of sites of rich in architectural heritage scatter all around the country. Some of these have unique characteristic. But due to lack of awareness and proper maintenance, we are going to lost them forever. It has been observed that conventional reconstruction and preservation systems are time consuming and expensive, moreover without highly skilled technical personnel proved futile. In such a situation an economic and flexible technique of conservation and documentation is inevitable for Bangladesh.

A 3D model or virtual model of a site or building not only provides some 'documentation' but also opens the possibilities for future research for preservationists, archaeologists, architects and historians. Even the interactive development of 3D models can empower the archaeologists to study, research and reconstruct. In this way new knowledge and better understanding about the investigated building can be attained and updated latter. An online documentation based on this digital data can be useful for a wider audience to "virtually" see and tour these sites and have a better understanding of the

history of Bangladesh from a remote place of any part of the world.

This paper has discussed some recent techniques and their potentialities in digital documentation of heritage buildings. It has been found while documenting in 2D way; a drawing prepared 'digitally' provides more flexibility for future modification. On the other hand, for 3D documentation, as 'Laser Scanning' is expensive and 'Photogrammetry' requires expert and technical knowledge. Whereas, "Geometric Modelling" is more appropriate for ease and economic '3D digital modelling'. Even this method requires more time and labour, but we believe this is most appropriate method as cheap labour is available in Bangladesh. However, Laser scanning can produce high-resolution and high quality photorealistic models. Where as our models seems less detailed and some accuracy is missing too. But we believe, being a self funded project it is the optimum that we have produced. We believe as our experiences and workmanship is developing, we can also produced highly detail and sophisticated models in future if we got support from industrial render engine and graphics hardware.

The study has found initially some sort of financial investment is required to get modelling software and equipments but once having those accessories can be used on latter study. The author expect this study will help the authority and related personnel to understand the importance of preserving our built heritage, related expenses and the means of suitable techniques of 'Digital Documentation' of our past.

However we have found by default these 3D models produced by Sketchup inherit potentialities of web publication for greater audience. We hope to digitally preserve all selected buildings around Khulna city and published them in the web in future. Thus a comprehensive digital documentation and wide dissemination can help the city dwellers as well as people around the world to receive, synthesize, assimilate and classify the colonial artefacts as components of perceiving the colonial image of Khulna city.

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## EXPLOITING THE CONTEMPORARY TOPCON IMAGING TOTAL STATION FOR CULTURAL HERITAGE RECORDING

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**KEY WORDS:** Imaging total station, Digital Camera, Rectification

### ABSTRACT:

The world's first total station to incorporate the very latest digital imaging technology to enhance Total Station fieldwork and extend the range of applications for the total station has been presented by Topcon just a few years ago. The implementation of imaging technology allows the image seen through the telescope to be viewed on the display screen of the instrument. This not only makes it easy to point the telescope to the required object for measurement, but instead of only the traditional map view of the surveyed points on the screen, you now see the measured points and lines appear on the real view of the area being measured. In addition you can now "Capture Reality" by storing the digital image along with the measurement data. In this paper the idea of photogrammetrically exploiting the images taken by this total station in conjunction to the recorded angles is thoroughly examined, as far as monoscopic images and plane objects is concerned for a start. An algorithm has been developed to produce rectified images without the need for any control points on the object. The implementation range and its limitations are examined and the results assessed for their accuracy

### 1. INTRODUCTION

#### 1.1 A contemporary Photo-theodolite

Back in the analogue era of Photogrammetry various models of terrestrial metric cameras were available in the market. They were grouped mainly into single cameras, stereocameras and, of course, photo-theodolites. The purpose of the latter was to provide to the user exact information about the camera orientation, in order to facilitate the photogrammetric operations in the analogue instruments. It was a necessity for the terrestrial applications, as they presented special difficulties, as opposed to, more or less, straightforward aerial mapping.

Through the years this information became obsolete, as analytical procedures took over and the analogue instruments were gradually replaced by analytical -at first- and digital photogrammetric workstations (DPW) later. However information about the orientation of the digital camera is always useful, especially in the case of terrestrial applications, which still present the same difficulties as before. Hence the position and attitude of the digital camera is very often sought in terrestrial applications, mainly in order to serve as initial values for the photogrammetric computations.

The Topcon GPT 7000i Imaging total station, which appeared in the market about four years ago, incorporates a digital camera and offers the capability of recording its attitude, i.e. orientation angles, at any pointing direction. Although not boosted by the manufacturer, it is maintained that this revolutionary total station could be used as a modern version of a photo-theodolite. In the following the first investigations towards this exploitation are presented.

### 2. INSTRUMENT DESCRIPTION

During InterGEO 2004 in Stuttgart, Topcon unveiled a revolution in Surveying Instrumentation in the form of the GPT-7000i (Figure 1). This is the world's first Total station to incorporate the very latest digital imaging technology to enhance Total Station fieldwork and extend the range of applications for the total station. According to the manufacturers the implementation of imaging technology allows the image seen through the telescope to be viewed on the display screen of the instrument. This not only makes it easy to point the telescope to the required object for measurement, but instead of only the traditional map view of the surveyed points on the screen, the user now sees the measured points and lines appear on the real view of the area being measured. In addition one may now "Capture Reality" by storing the digital image along with the measurement data. However there is little reference to the metric exploitation of the digital images captured by the instrument (<http://www.topconeurope.com>).



Figure 1: The Topcon GPT 7000i Imaging total station

The GPT 7000i Series basic features include:

- Dual-view integrated CCD camera with 'wide and finder view'
- Windows CE.NET 4.2 operating system
- Extra-large QVGA LCD TFT colour display
- GUI (Graphical User Interface)
- Field images recorded with the field coordinate data
- TopSURV™ on-board data collection software
- Pinpoint reflectorless measuring up to 250m
- Single prism measuring up to 3000m
- By adding optional digital imaging software, like e.g. the Topcon PI3000, one can combine multiple job site photos and create 3D models and point clouds

Windows CE technology on the GPT-7000i imaging total station provides a bright graphic display, touch screen display, more functionality, better support for standard accessories like Bluetooth® wireless technology and more available software.

The instrument features two different digital cameras: One coaxial to the telescope, called finder view ( $f = 248.46\text{mm}$ ), which records the details of the point measured each time, and a second one above the telescope axis, but within the same housing, called wide area view. The specifications of this latter camera are:

Image:	0.3M pixels CMOS Sensor
Number of effective pixels:	640 x 480 (VGA)
f:	8 mm
Digital zoom magnifications:	0.25, 0.5, 1.0, 2.0 x
Minimum focusing distance:	2 m

### 3. METHODOLOGY

#### 3.1 Instrument Operation

While measuring points with the instrument, there are several options available to the user. Firstly, with each point recorded, the finder view camera acquires an image of the details around the recorded point. Optionally, the user may request the acquisition of an additional image with the wide area view camera. Depending on the distance of the object from the instrument, this latter image may be exploited for photogrammetric use. The first approach considered in this report, concerns the single image exploitation, i.e. the image rectification.

#### 3.2 Image Rectification

Image rectification is a single-image photogrammetric process, which applies the projective transformation to images of planar objects, in order to produce orthogonal projections thereof. In the two dimensional image the third dimension "disappears" and the reversal of the process requires a second geometric locus of the point in 3D space (i.e. a second image in most cases). In the case of a two dimensional object, i.e. a planar object (like e.g. a building façade), there is no third dimension, hence the reversal of the process is possible using a single image. This process actually is a two dimensional projective transformation relating the two planes: The object and the image. This transformation is described as follows:

$$X = \frac{a_1x + a_2y + a_3}{a_7x + a_8y + 1} \quad Y = \frac{a_4x + a_5y + a_6}{a_7x + a_8y + 1}$$

where:

- $X, Y$  : Co-ordinates on the object plane
- $x, y$  : Co-ordinates on the image plane
- $a_1) a_8$  : Projective transformation coefficients

Normally the relative position of at least four points (Ground Control Points, GCP's) should be known for the rectification to be feasible. For the analytical determination of the projective transformation parameters their co-ordinates in both planes are desired. Alternatively, each transformation coefficient may be expressed with the help of the following parameters, which do not include the co-ordinates of the points:

- $X_o, Y_o, Z_o$  : The geodetic co-ordinates of the camera projection centre
- $x_o, y_o$  : The principal point co-ordinates
- $c$  : The camera constant
- $\omega, \phi, \kappa$  : The basic rotations of the camera axis

It is obvious that a total station set-up over a point may provide part of the above information, i.e. the co-ordinates of the station point and the orientation of the telescope axis. Hence a methodology is sought to combine this available information with some additional image parameters (i.e. the co-ordinates of the principal point and the camera constant) in order to perform image rectification without the need for ground control points (GCP's).

#### 3.3 Proposed methodology

The equations relating the eight coefficients of the projective transformation to the above parameters are (Kraus, 2003) :

$$a_1 = -\frac{X_o r_{13} - Z_o r_{11}}{x_o r_{13} + y_o r_{23} + c r_{33}} \quad a_2 = -\frac{X_o r_{23} - Z_o r_{21}}{x_o r_{13} + y_o r_{23} + c r_{33}}$$

$$a_3 = \frac{X_o (x_o r_{13} + y_o r_{23} + c r_{33}) - Z_o (x_o r_{11} + y_o r_{21} + c r_{31})}{x_o r_{13} + y_o r_{23} + c r_{33}}$$

$$a_4 = -\frac{Y_o r_{13} - Z_o r_{12}}{x_o r_{13} + y_o r_{23} + c r_{33}} \quad a_5 = -\frac{Y_o r_{23} - Z_o r_{22}}{x_o r_{13} + y_o r_{23} + c r_{33}}$$

$$a_6 = \frac{Y_o (x_o r_{13} + y_o r_{23} + c r_{33}) - Z_o (x_o r_{12} + y_o r_{22} + c r_{32})}{x_o r_{13} + y_o r_{23} + c r_{33}}$$

$$a_7 = -\frac{r_{13}}{x_o r_{13} + y_o r_{23} + c r_{33}} \quad a_8 = -\frac{r_{23}}{x_o r_{13} + y_o r_{23} + c r_{33}}$$

For these parameters to be determined analytically, camera calibration and total station orientation are needed, in order to establish exactly the position of the camera projection centre and the attitude of the camera axis in relation to the telescope axis and the position of the total station. Once these parameters are computed, the transformation between the two systems will be established and, consequently, any point measured on the image could be transformed to the geodetic system on the plane. The only presupposition is that the geodetic system should be defined on the planar object (Figure 2).

The above transformation may be executed for each pixel on the initial image. Thus the result will be a rectified image of the planar object, which obviously is an orthogonal projection.

#### 3.4 Camera Calibration

For the determination of the interior orientation parameters of the camera of the image station, but also for the determination of the exact position of the camera's projection centre in

relation to the total station's centre a standard camera calibration procedure was employed.

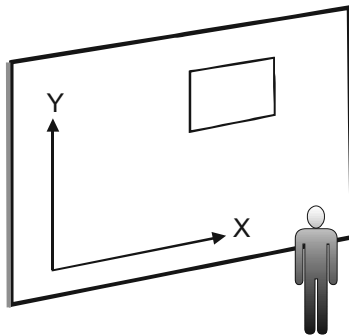


Figure 2: The geodetic reference system in the plane object

For this purpose several images of the indoor test field of the Metrology Centre of NTUA (Figure 3) were taken by the image station's camera. At the same time the exact position of the total station was determined with the help of a Leica TC 5005 theodolite with high accuracy.

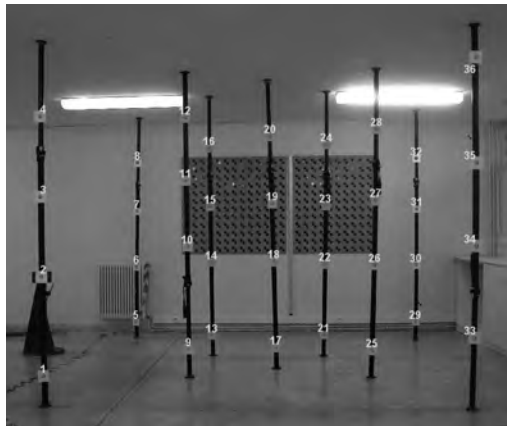


Figure 3: The indoor test field

A suitable camera calibration own developed software was employed. It actually performs a self calibrating bundle adjustment, thus determining both the exterior and interior orientation parameters of the camera. The calibration results are summarized in Table 1.

Principal point			
xo (pixel)	yo (pixel)	xo (mm)	yo (mm)
319,682	220,736	1,790	1,236
Camera constant			
c (pixel)	c (mm)	Nominal value (mm)	
1430,485	8,010716	8	

In addition, the calculations proved that the camera projection centre is located 45.2mm vertically above and 48.932mm to the front of the point of intersection of the main instrument axes. This is also indirectly verified by the manufacturer's brochure.

### 3.5 Direct Rectification

A first approach for acquiring a rectified image with the imaging total station is the following: Provided a planar object

is being measured, the imaging station's telescope, and hence the incorporated camera may be oriented in such a way that its axis is perpendicular to the object's main plane. This may be achieved by calculating the plane's azimuth and calculating accordingly the value of the horizontal angle of the telescope. In this way a directly "rectified" image of the object is acquired, without the need for ground control points, as the calculation may be based on arbitrary points determined using the reflectorless ability of the imaging station.

## 4. SOFTWARE DEVELOPED

However, this may not always be possible, as a different orientation of the telescope may be required for the whole object of interest to be imaged. In this case a different approach is required and hence the proposed methodology is applied.

Suitable software has been developed using MATLAB<sup>®</sup> environment. This software uses the values of the calibration parameters, the co-ordinates of the point on which the imaging total station is set up and the values of the horizontal and vertical angles measured towards the planar object, in order to calculate the projective transformation parameters and perform the image transformation, thus producing a rectified image. The main steps of the software are the following:

- Input of the calibration parameters
- Input of the imaging station co-ordinates
- Read-in of the horizontal and vertical angles
- Determination of the eight parameters of the projective transformation
- Calculation of the parameters of the reverse projective transformation
- Resample original digital image to produce the rectified one, with pixel size defined by the user

A first implementation of the above described software was performed with images acquired in the Technological and Cultural Park of NTUA in Lavrio. The buildings of the old French Mining Company present mainly planar surfaces and interesting details (Figure 4). Several tests were performed during the field work including directly acquiring a rectified image (see par. 3.5) and rectifying images using the developed software.



Figure 4: The buildings in the Technological and Cultural Park of NTUA in Lavrio

Such an example involves the original image shown in Figure 5. It was acquired with the imaging total station from a point with known co-ordinates ( $X=100$ ,  $Y=11.340$ ,  $Z=100$ ) in a local co-ordinate system. The details of this particular image are:

- Horizontal angle =  $221^{\circ}8062$
- Vertical angle =  $90^{\circ}.0006$

- Principal distance = 1430.485 pixels
- Principal point co-ordinates  $x_0=319.682$ ,  $y_0=220.736$  pixels

The last two result from the camera calibration procedure, which has been described before. With a suitable calculation from the above data the omega and phi rotations may be calculated, as they refer to a different co-ordinate system (Figure 2). Also the eccentricity of the camera projection centre referring to the theodolite's central point has been taken into account in order to determine the eight projective transformation parameters.



Figure 5: Original image taken with the Topcon 7000i Imaging Total Station

The same original image has been rectified both with the software developed and standard digital rectification software which requires the co-ordinates of control points on the objects planar surface. After the completion of the two procedures the two rectified images have been compared with a simple geodetic restitution of the object, which was performed with the imaging total station. The rectified images were also inserted in a CAD environment and overlaid with the vector restitution (Figures 6 and 7) with very promising results.



Figure 6: The rectified image with the rectification software overlaid with the vector restitution of the object

The first comparison calculations show that the two methods produce similar results in terms of accuracy and image quality. Of course further and more thorough tests are already underway and will be reported in due course.

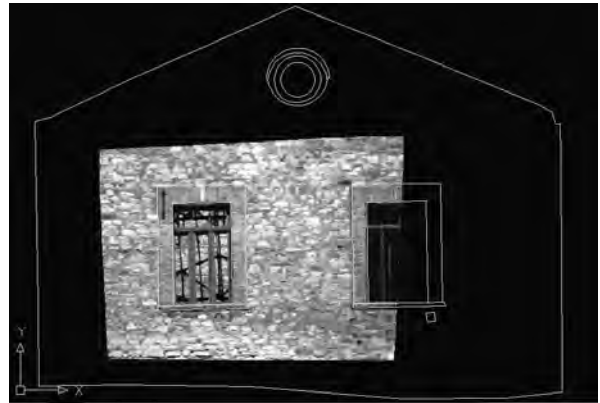


Figure 7: The rectified image with the developed software overlaid with the vector restitution of the object

## 5. EVALUATION & FUTURE OUTLOOK

It has been proven that the idea of direct rectifying images taken by the imaging total station is quite promising. It is for the first time that geodetic measurements and imaging procedure may be integrated into one action. Hence the idea of exploiting the simultaneously acquired data leads to improvement of speed and reduction of cost, as only one piece of instrumentation is required.

Moreover users are freed from the need of measuring and determining ground control points (GCP's), since the necessary information is recorded together with the image acquisition process. In addition the potential user is freed for the necessity of using an expensive standard block adjustment software for achieving the same result.

However, the characteristics of the digital camera incorporated into the imaging station are still not entirely adequate for extended applications. It is believed that it is only a matter of time until they improve, i.e. increase the image spatial analysis, improve the camera constant or decrease the pixel size. They are all depending on technological advances which are inevitable in the near future.

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## MOBILE LIDAR MAPPING FOR URBAN DATA CAPTURE

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**KEY WORDS:** Three-dimensional, Point Cloud, Urban, LIDAR, Façade Interpretation

### ABSTRACT:

Terrestrial laser scanning is meanwhile frequently used to capture high quality 3D models of cultural heritage sites and historical buildings. However, the collection of dense point clouds can become very labor expensive, especially if larger areas like complete historic sections of a town have to be captured from multiple viewpoints. Such scenarios opt for vehicle based mobile mapping systems which allow for so-called kinematic terrestrial laser scanning. Within the paper the performance of this approach will be described on example of the “StreetMapper” system. There 3D data collection is realized by a combination of four 2D-laser scanners, which are mounted on a vehicle based, while a high performance GNSS/inertial navigation system provides the required georeferencing information. Within our investigations the accuracy of the measured 3D point cloud is determined based on reference values from an existing 3D city model. As it will be demonstrated, the achievable accuracy levels is better than 30mm in good GPS conditions and thus makes the system practical for many applications in urban mapping.

### 1. INTRODUCTION

Terrestrial laser scanning (TLS) is frequently used to provide high quality 3D models of cultural heritage sites and historical buildings. Based on the run-time of reflected light pulses, these sensor systems allow for the fast, reliable and area covering measurement of millions of 3D points. However, data collection from multiple viewpoints, which is usually required for the complete coverage of spatially complex urban environments, can result in a considerable effort. Thus, 3D data capturing by so-called static TLS is usually restricted to smaller areas, which can be covered by a limited number of viewpoints. However, cultural heritage applications, which are aiming at architectural documentation can require data collection for complete places or historic parts of a town. In such scenarios, dynamic TLS from a moving platform is advantageous. Such mobile mapping systems integrate terrestrial laser scanners with a suitable system for direct georeferencing. By these means a rapid and cost effective capturing of dense 3D point clouds even for larger areas is feasible.

Within this paper, the performance and accuracy of the mobile mapping system “StreetMapper” will be discussed. Originally, this first commercially available fully integrated vehicle based laser scanning system was developed for measurement and recording of highway assets (Kremer & Hunter 2007). The StreetMapper features four 2D laser scanners integrated with a high performance GNSS/inertial navigation system. As it will be demonstrated, this configuration allows an efficient collection of dense and area covering 3D point clouds also in urban environments. Since we are aiming at the collection of architectural heritage, the main interest of our investigations is the evaluation of data quality for points measured at building façades. For this purpose vertical building faces are used as references surfaces, which are extracted from an existing 3D city model.

After a brief description of the components and the theoretical accuracy potential of the StreetMapper system in the following section, the collection of the test data is discussed in section 3. Section 4 covers the presentation and interpretation of our accuracy investigations. The final section will then conclude with a discussion and demonstrate the applicability of such data sets for the aspired collection of façade geometry.

### 2. STREETMAPPER SYSTEM

The StreetMapper mobile laser scanning system collects 3D point clouds at a full 360° field of view by operating four 2D-laser scanners simultaneously. The configuration of the system with the additional GPS/inertial components for positioning and orientation of the sensor platform is depicted schematically in Figure 1.

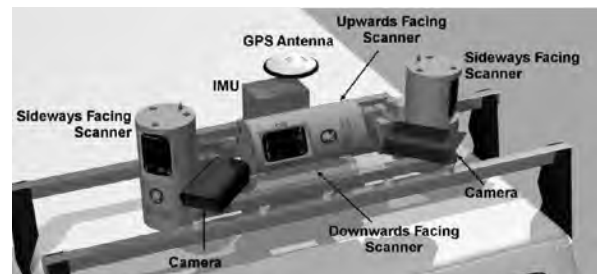


Figure 1 : Configuration of the Streetmapper system.

The required direct georeferencing during 3D point cloud collection is realized by integration of observations from GNSS (Global Navigation Satellite Systems) and Inertial Measurement Units (IMU). For this purpose the TERRAcontrol system from IGI, Germany is used. In the standard configuration the StreetMapper uses the NovAtel OEMV-3 card from NovAtel Inc, Calgary, Canada for GPS and GLONASS measurements.

However, for the project described within this paper, only GPS was operated. Since the system is optimized for data processing in the post processing mode, the real time correction, which would be available from OmniStar HP are not used.

For position and attitude determination the TERRAcontrol GNSS/IMU system is using the IGI IMU-IIId (256Hz) fiber optic gyro based IMU. This Inertial Measurement Unit is successfully operated with a large number of airborne LIDAR systems and aerial cameras. Nominally, the angular accuracy of the system is below  $0.004^\circ$  for the roll and pitch angle. This accuracy cannot be fully exploited for the short scanning distances in this application. However, the high accuracy strongly supports the position accuracy in areas of weak or missing signal of the Global Navigation Satellite System. To gain a better aiding of the inertial navigation system during periods of poor GNSS, the GNSS/IMU navigation system for the StreetMapper is extended by an additional speed sensor. Among other benefits in the processing of the navigation data, the speed sensor slows down the error growth in periods of missing GNSS, like in tunnels or under tree cover.

In our test configuration image collection was realized by a normal consumer video camera. While this is sufficient to enable a better visual interpretation of the collected point clouds, higher demands on imaging quality can be fulfilled by operating a digital still video camera, which can be optionally mounted together with the sensors on the rigid platform.

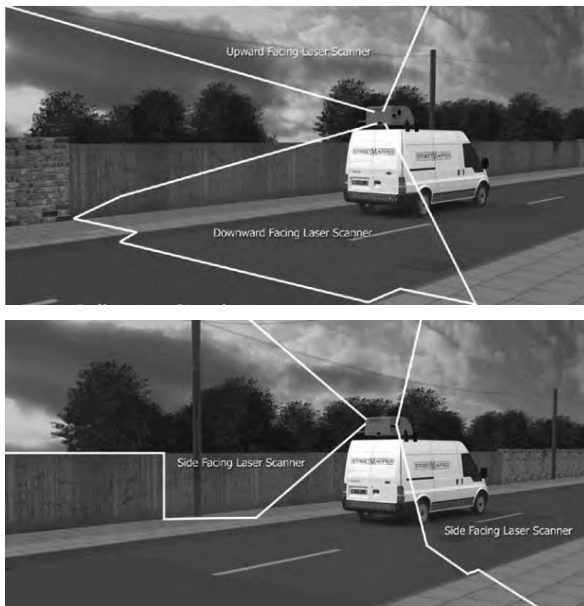


Figure 2: Field of view of the single laser scanners

The field of view available from the combination of the four different laser scanners is depicted in Figure 2. The mounting position and angles of the scanners aim to provide maximum coverage with some overlapping data between each adjacent scanner for calibration purposes. All scanners were manufactured by Riegler Laser Measurement Systems, Horn, Austria. In our test configuration, two Q120i profilers provide the upward and downward looking view at a mounting angle of  $20^\circ$  from the horizontal, respectively. Nominally, the Q120i has maximum range of 150 m at an accuracy of 20 mm. The side facing view to the left (with respect to the driving direction) is generated by a Q140 instrument. The respective scans to the right are measured by a Q120. The mounting angle for both of

the side facing instruments is  $45^\circ$ . All four scanners were operated at a maximum scan angle of  $80^\circ$ .

### 3. TEST CONFIGURATION

In order to investigate the georeferencing accuracy of a mobile mapping system like StreetMapper, area covering reference measurement are required. As an example (Barber et al 2008) used approximately 300 reference coordinates, which were measured by Real Time Kinematic GPS at corner points of white road markings. During their investigations of the StreetMapper system, these points were then identified in the scanner data due to the amplitude of the reflected pulses. Alternatively to the measurement of such singular points, which can be provided at relatively high accuracies, 3D point clouds can be measured by static TLS using standard instruments and used as reference. However, this is only feasible for selected areas due considerable effort for data collection. For this reason, our investigations are based on area covering reference surfaces which are provided from an existing 3D city model for the city of Stuttgart.

This 3D city model is maintained by the City Surveying Office of Stuttgart (Bauer & Mohl, H. 2005). The roof geometry of the respective buildings was modeled based on photogrammetric stereo measurement, while the walls trace back to given building footprints. These outlines were originally collected by terrestrial surveying for applications in a map scale of 1:500. Thus, the horizontal position accuracy of façade segments are at the centimeter level since were generated by extrusion of this ground plan. Despite the fact that the façade geometry is limited to planar polygons, they can very well be used for our purposes.



Figure 3: 3D city model used as reference data with overlaid trajectory

Figure 3 shows a 3D visualisation of the 3D city model used for the following tests. Additionally, a part of the measured trajectory is overlaid. This trajectory was captured during our test of the StreetMapper system within an area in the city centre of Stuttgart at a size of 1.5 km x 2km. During our test a distance of 13 km was covered in about 35 minutes. The measurement of the respective point clouds was realized at a point spacing of approximately 4cm.



Figure 4 : Point cloud from StreetMapper aligned with available 3D city model.

Figure 4 exemplarily depicts a part of the StreetMapper point cloud at the historic Schillerplatz in the pedestrian area of Stuttgart. The measured points are overlaid to the corresponding 3D building models in order to show the quality and amount of detail of the available data.

#### 4. ACCURACY INVESTIGATIONS

In order to assess the precision of the system, first the internal accuracy of GNSS/IMU processing as provided by the implemented Kalman filter is presented in section 4.1. Section 4.2 discusses the preprocessing of the point clouds within our evaluation scenario, while section 4.3 describes the use of the available 3D building models to determine the accuracy of the collected point clouds with respect to these reference surfaces.

##### 4.1 Georeferencing accuracy

Like in airborne LIDAR, the accuracy of dynamic terrestrial LIDAR mapping from a mobile platform mainly depends on the exact determination of the position and orientation of the laser scanner during data acquisition. However, the GNSS conditions in a land vehicle are deteriorated by multipath effects and by shading of the signals caused by trees and buildings. Compared to an aircraft these different conditions in a land vehicle lead to different requirements for the used GNSS/IMU system.



Figure 5 : Measured trajectory with number of visible satellites, overlaid to DSM of test area.

Problems due to GNSS shading are clearly visible in Figure 5 which depicts the visible number of satellites during our test. In addition to the colour coded trajectory, a grey value representation of the respective Digital Surface Model is used

as the background of the figure to give an idea of the test area's topographic situation. Rather large areas of missing GNSS especially occur at very narrow streets. These areas were mainly situated in a pedestrian area of Stuttgart, where the GNSS signal was additionally shaded by a number of trees.



Figure 6 : Estimated horizontal accuracy of the trajectory after GNSS/IMU post processing.

Figure 6 gives the horizontal positioning accuracy which could be realised by GNSS/IMU post processing using the TERRAoffice software. As it is visible, under good GNSS conditions, an accuracy of the trajectory of about 3cm could be realized. For difficult conditions, where the GPS signal is shaded over larger distances, the error increases to some decimeters. However, despite the very demanding scenario it still can be kept below 1m. For mobile mapping applications, the distance between the scanner and the measured object is typically some ten meters, compared to several hundred meters for airborne laser scanning. Therefore the contribution of the GNSS positioning error to the overall error budget is much larger than the contribution of the error from the attitude determination.

##### 4.2 Selection of point clouds

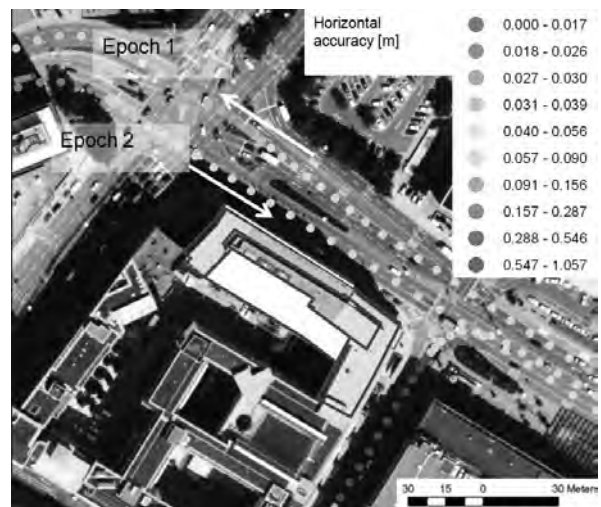


Figure 7: Ortho image with measured trajectory, selected building and part of the facade overlaid.

Figure 7 shows the ortho image for a part of our test area. In addition to the measured trajectory, the footprint of a building model, which was exemplarily selected as reference object from the available 3D city model is overlaid as a blue polygon. From this building model a façade segment is again selected, which is marked as yellow line. By these means a suitable reference



surface is available to investigate the overall error of the 3D point cloud as collected from the StreetMapper system.

Figure 7 also depicts the trajectory of the system during scanning. As it is visible, the façade was measured during 2 different epochs at two different driving directions. In epoch 1 the building was visible on the left with respect to the driving direction, while during epoch 2 the building was on the right. The georeferencing accuracy of the respective trajectory, which was provided by GNSS/IMU processing, is represented by colour coding. Since the street in front of the selected façade is relatively broad, good GPS visibility is available for that area. This resulted in an accuracy of about 3cm for the horizontal position as provided from the Kalman filter. The points, which represent the trajectory, were generated for time intervals of 1sec, clearly showing the process of slowing down and acceleration of the vehicle

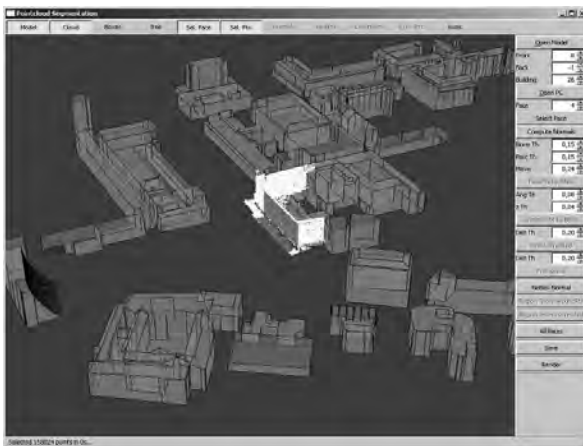


Figure 8 : 3D city model with selected reference building and corresponding section of measured 3D point cloud.

Figure 8 gives a screenshot of our GUI, which was used to select suitable reference buildings for the measured point clouds. For this purpose, the user then can interactively select single buildings and building facades from the available 3D city model. The relevant 3D point measurements are then extracted automatically by a simple buffer operation. Within Figure 8, the available LiDAR points for the building already depicted in Figure 7 are marked in yellow, while measurements corresponding to the selected façade are marked in red and the selected building is highlighted in green.

### 4.3 Investigation of point clouds

After the selection process, the respective façade points are transformed to a local coordinate system as defined by this façade plane. The resulting vertical distances of the measured points can then be used for a further error analysis. In order to get a first impression of the measurement accuracy, Figure 9 shows the vertical distances of the LiDAR measurements represented as colour coded points. As it is visible, points were selected from 5.8cm in front to 61.0cm behind the given façade plane. Most of the points behind the plane refer to measurements at window surfaces.

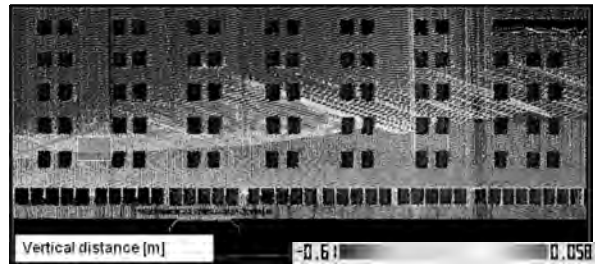


Figure 9 : Color-coded vertical distances of the measured 3D point cloud with respect to the corresponding façade surface.

For further analysis, the measured LiDAR points were used to estimate planar surface patches by least squares adjustment, which then were compared to the given façade polygon from the city model. In this way, the points within the white polygon of Figure 9 resulted in a shift between the estimated and the reference plane of -13.8cm. The horizontal accuracy of the given building façade is in the order of several centimeters. Thus, this shift can in principle result both from errors in the LiDAR measurement and the reference model. For this reason further investigation were carried out using additional features of the collected 3D points like the measured range, the look angle both with respect to the sensor platform and the reference façade, the respective scanner and the time of measurement. This is feasible since the StreetMapper provides the 3D point cloud in the ASPRS LAS format (Graham 2005).



Figure 10: Points measured during epoch 1 from upward and left looking scanner, represented by yellow and red points, respectively.

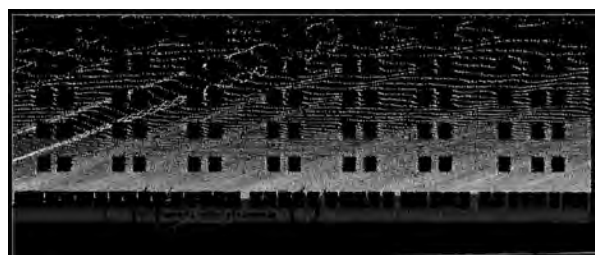


Figure 11: Points measured during epoch 2 from upward and right looking scanner, represented by yellow and blue points, respectively.

For our investigations, the separation of the measured point cloud with respect to the different scanners and measurement epoch was of special interest. As already discussed, the façade was measured during 2 different epochs. Figure 10 shows the points measured during the first pass of the vehicle (epoch 1). In this epoch measurements from the left and the upward looking scanner are available, which are represented by the red and yellow points, respectively. During these measurements, the perpendicular distance between the vehicle and the building façade was approximately 25m, resulting in a mean value of the measured ranges of about 41m. Figure 11 depicts the

measurements during the second pass of the vehicle, when the building was on the right side with respect to the driving direction. Thus, points from the right scanner looking scanner, (blue), are available together with points from the upward looking scanner (yellow). Due to the shorter distance between vehicle and the building, only the lower part of the façade was captured from the side looking scanner in the second epoch. Planar patches were then estimated and compared to the façade surface for the respective scanners and epochs. The results of these investigations are summarized in Table 1.

Scanner	Epoch	Shift [cm]
l+r+u	1+2	-13.8
l	1	-13.5
r	2	-12.6
u	1+2	-15.4
u	1	-25.7
u	2	-0.08

Table 1: Estimated planes for the selected patch, separated for different scanners and measurement epochs.

The determined shift values within Table 1 again refer to points within the white polygon already depicted in Figure 9. The first line of Table 1 shows the result for the combination of point measurements from all scanners (left, right, up, l+r+u) at all epochs (1+2). As already discussed in section 4.2, the shift of -13.8cm between the measured plane and the reference façade is in the order of the available quality of the building model.

For perfect georeferencing and system calibration, no differences between the measurements from different scanners at different epochs should be visible. However, the colour coded vertical distances for all available points already depicted in Figure 9, apparently show some systematic effects. These effects are verified by the further values in Table 1. The second row gives the shift for an adjusted plane using the points from the left looking scanner (l) captured during period 1 (red points in Figure 10). This resulted in a distance of -13.5cm with respect to the given façade. These measurements fit very well to the shift of the points measured from the right looking scanner (r) in period 2 (blue points in Figure 11), which resulted in a distance of -12.6cm. However, if data from the upward looking scanner (u) (yellow points in Figure 10 and Figure 11, respectively) is examined for periods 1 and 2, the shift is -15.4cm. If these points are further separated with respect to the different epochs (rows 5 and 6) the shift is -25.7cm for epoch 1 and -0.08cm for epoch 2.

As it is visible in rows 2 and 3 of Table 1, the measurements from the left and right looking scanner, which were captured at different epochs result in a difference between the estimated planar patches of just 0.9cm. This fit indicates a quite good georeferencing accuracy for both epochs and a good calibration of both scanners. Apparently, the differences of the estimated planes to the reference plane apparently result from the error in the given 3D building model. In contrast, the estimated planar patches from the measurements of the upward looking scanner show considerable differences between epoch 1 and 2. The opposite signs of the deviations apparently trace back to the different driving directions during point measurement. Thus, the deviation can be explained by an improper boresight calibration of the upward looking scanner. This effect could be verified for other building facades of our test data set.

In general, such calibration problems, which are well known from the processing of airborne LiDAR and can be solved by suitable post processing. In our test, the boresight calibration was refined for the upward scanner, which resulted in a change

of that scanner orientation (heading) with respect to IMU of 0.1°.

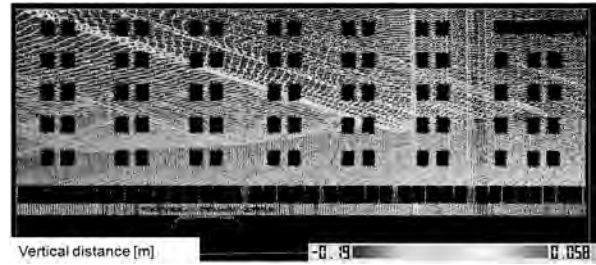


Figure 12 Color-coded vertical distances after refined calibration.

After the refined calibration the georeferenced 3D point cloud was again used to compute vertical distances with respect to the corresponding façade surface. The result is depicted in Figure 12. In contrast to Figure 9, systematic effects of the color-coded vertical distances are no longer visible.

Scanner	Epoch	Shift [cm]	Std.dev. [cm]
l+r+u	1+2	-7.8	4.7
l+u	1	-7.4	4.6
u+r	2	-9.0	4.1

Table 2 : Estimated planes for the completed building façade

This improvement is also verified by the results in Table 2. The shift and RMS values in Table 2 were determined from all LiDAR points for the complete building façade, which had a size of 26m x 60m. As it is visible, the values fit very well for the different epochs and scanners. Apparently, remaining deviations of the measured points can be explained by the limited accuracy of façade from the 3D building model.

#### 4.4 Shaded GPS conditions

As it is already visible in Figure 5 and Figure 6, for some areas the shading of the GNSS satellites results in a georeferencing error up to 1m for the horizontal position. Despite the limited quality of the absolute position in the mapping coordinate system, such 3D point measurements during bad GPS conditions are still useful, especially if mainly their relative position is exploited.

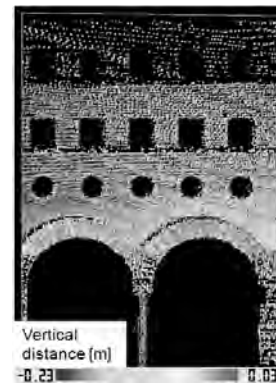


Figure 13: Captured point cloud during shaded GPS conditions.

For the example given in Figure 13, rather large differences between the reference building and the estimated plane occurred to long term GPS shading in that area. However, the standard deviation of the estimated planes is 5cm if points from the left and upward looking scanner are combined and 2.6cm if the points are separated for each scanner. For this reason, the

collected point cloud can still be used for applications like precise distance measurements or the extraction of features of interest like windows or passages, if a certain error for their absolute position is acceptable.

## 5. CONCLUSIONS AND OUTLOOK

Within our study, the feasibility of the StreetMapper system to produce dense and accurate 3D measurements has been demonstrated. Such densely sampled 3D points at urban areas can for example be used very well to geometrically reconstruct fine geometric details of building facades like windows, balconies, stonework and ornaments. Within our work, the required interpretation of terrestrial LiDAR point clouds is supported efficiently by the use of a coarse building model that describes the overall geometry of the building in a polyhedral approximation (Becker & Haala 2007). As already discussed in section 3 such coarse representations are frequently available from existing 3D city models, which are usually generated from airborne data collection.



Figure 14 : Facade reconstruction for the “Lindenmuseum” with and without measured 3D points overlaid.

Figure 14 depicts an example of our ongoing work, where the planar facades of the existing 3D city model of Stuttgart is refined using the collected StreetMapper point clouds. As it is visible, geometric façade structure like windows and doors are automatically generated for the respective coarse 3D building model. Existing 3D city models can also be used to improve the absolute accuracy of the georeferencing process of the 3D point cloud collection. This can for example be necessary for areas of shaded GPS conditions. For this purpose the measured 3D point cloud can be registered to the given 3D building model by an iterative closest point (ICP) algorithm as presented in (Böhm & Haala 2005).

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# **Digital Archives Online**



# INTEGRATION, MANAGEMENT AND PRESERVATION OF ARCHAEOLOGICAL DIGITAL RESOURCES IN THE ERA OF INTEROPERABILITY AND DIGITAL LIBRARIES: THE NEW INFORMATION SYSTEM FOR THE SUPERINTENDENCE OF NAPLES AND POMPEII

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**KEY WORDS:** Archaeology, Database, Digital Libraries, Digital preservation, Geographic Information System, Interoperability, Metadata standards, Open Source Software.

## ABSTRACT:

The project is financed by ARCUS S.p.a. and developed by the Scuola Normale Superiore of Pisa (SNS) together with the Archaeological Superintendence of Naples and Pompeii (SANP). The new SANP Information System has been designed by SNS and implemented by Liberologico S.r.l. Its main requisite is the ability to migrate various resources into one platform for the management of archaeological information related to the Pompeii site and the area around Mount Vesuvius, including Herulaneum, Stabiae, Oplontis and Boscoreale. These resources include text, 2D and 3D images, audio and video documents, geographic information, and were previously managed by different software and stored in various repositories. Moreover, the System permits the harvesting of its data and metadata from other repositories. Specifically, the data schemes adopted for Pompeii's resources, which comply with the standard models of ICCD, have been mapped into the Dublin Core Application Profile designed by SNS for CulturalItalia under commission of the Italian Ministry of Culture. This mapping will allow the harvesting of the system's contents from the Portal CulturalItalia and interoperability with other repositories.

## 1. INTRODUCTION

The ARCUS - SANP - SNS Project is developed by the Scuola Normale Superiore of Pisa (SNS) in collaboration with the Archaeological Superintendence of Naples Pompeii (SANP) and funded by ARCUS S.p.a., a company promoting arts, culture and performances, whose capital is entirely subscribed by the Italian Ministry of Economy and whose actions are planned by the Ministries of Culture and of Infrastructures.

The Project is regulated by two agreements among the three abovementioned bodies. The first one started in April 2005 and ended in March 2008. It produced the new SANP Information System. The system has been designed and developed by SNS in collaboration with Sistemi Informativi S.r.l. Liberologico. The second agreement (from May 2007 to December 2008) will look into the design and publication of an official website on the Vesuvian Archaeology. It also will produce, in cooperation with the INDACO Department of the Politecnico of Milan, a prototype of 3D model representing the Forum of Pompeii, aimed at defining some best practices for data acquisition and rendering of 3D models.

The main requisite of the SANP Information System is the ability to migrate various existing resources into one platform for the management of archaeological information related to the Pompeii site and the territory administrated by the Superintendence of Pompeii, including Herulaneum, Stabiae, Oplontis and Boscoreale. These resources include text, 2D and 3D images, audio and video documents, geographic information, and were previously managed by different software and stored in various repositories.

Another important requisite is the scalability of the system, and its capability of supporting different metadata schemas.

The System will be maintained by the SIAV (Archaeological Information System for the Geographic Area of Mount Vesuvius), which is an internal office of the SANP, and will be used both for internal purposes (cataloguing, documentation, preservation, management of archaeological heritage) and for external communication.

In April 2008, the unexpected creation of the new "Archaeological Superintendence of Naples and Pompeii" joining the two pre-existing Superintendencies "of Pompeii" and "of Naples", brought into light the need to integrate in the System also the digital resources pertaining to the Neapolitan area: an implementation plan is currently under development. Moreover, the System permits the harvesting of its data and metadata from other repositories via OAI-PMH (Open Archive Initiative – Protocol for Metadata Harvesting, see: OAI Executive, OAI Technical Committee, 2004).

Specifically, the data schemes adopted for Pompeii's resources, which comply with the standard models of Italian Central Institute for Cataloguing (ICCD – see: ICCD, Cataloguing Standards, 2008), have been mapped into the Dublin Core Application Profile (see: MiBAC, SNS, 2007; ICCD, SNS, 2008) designed by SNS for the Italian Culture Portal "CulturalItalia" (MiBAC, CulturalItalia, 2008. See also: MiBAC, CulturalItalia, technical documentation, 2008) under commission of the Italian Ministry of Culture (MiBAC).

This mapping will allow the harvesting of the System's contents from CulturalItalia and interoperability with other repositories adopting Simple and Qualified Dublin Core (see: DCMI, 2008; DCMI Usage Board, Terms, 2008).

## 2. ANALYSIS AND DESIGN OF THE SYSTEM

The SANP represents a complex case-study for the designing of an interoperable Information System, due to the peculiarity of the patrimony under its administration, to the extension of the geographic area on which it is disseminated and to the special state of autonomy assigned to the former Superintendence of Pompeii by the Ministry since 1998.

The managing strategies of the SANP aim at simplifying and defining the internal procedures through the progressive digitisation of the huge quantity of data produced by its offices and through their centralisation into the SIAV office, which will maintain the System.

The SANP Information System has been therefore designed to collect in one interoperable System the existing digital resources maintained by the SIAV and other resources on the Vesuvian heritage produced by external Bodies, also foreseeing the integration of other resources that will possibly be produced in the future.

### 2.1 Contents and domain

When the Project started (2005) the existing digital contents that already were in possession of the SIAV pertained to the huge archaeological patrimony disseminated in the large area around Mount Vesuvius.

The analysis identified various existing digital resources to be integrated in the System, very different between each other both on the content and in their format. Such resources were previously managed by different software and stored in various repositories:

- **Geographic data:** three Geographic Information Systems (GIS), managing various information: the “Neapolis” GIS, containing themes related to the architectural structures in the whole Vesuvian area; “A plan for Pompeii” GIS, with data about findings situated at, or originating from, the archaeological buildings and information on the conditions of the buildings in the Pompeii area; the “Vesuvian Area” GIS, maintaining information for monitoring the volcanic risk in the Vesuvian area, directed to the Regional territorial action-planning.

- **Cataloguing data:** resources resulting from various cataloguing campaigns conducted by the Superintendence during the last twenty years. All those information were managed by various software and had different metadata schemas. They were not related to each others and were not interoperable. They mainly consist in: cataloguing charts of the archaeological objects (mostly paintings and mosaics from Pompeii) and monuments (private houses and public buildings from all over the Vesuvian area). These charts are structured according to the standard cataloguing schemes of ICCD or with schemes specially designed by the Superintendence for describing its peculiar heritage; digitised images (mainly drawings and photographs); charts and related digitised texts pertaining to the excavation diaries and reports by the archaeologists.

Along with these already existing contents, the analysis brought into light the opportunity to integrate in the System a huge quantity of information produced during the years by external actors. In fact, an effective exploitation strategy carried out by the Superintendence led to several agreements with Italian and foreign institutions and enterprises, for promoting and allowing researches, excavation campaigns, restoration activities, etc. Such collaborations produced publications, exhibitions, databases, 3D reconstructions, documentaries and other high quality multimedia resources, that in the future could be stored in the System.

In conclusion, the analysis identified as the main requisites of the System interoperability, scalability and flexibility, as the System had to be capable of managing different kinds of inter-related and geo-referenced data in different formats, and of supporting various metadata schemas that could be updated or could be completely substituted by other schemas in the future.

### 2.2 Requirements

As a result of the analysis, the three partners involved in the Project fixed that the System had to simplify the management, preservation and exploitation of the heritage administrated by the SANP and to guarantee the internal storage and preservation of data produced by its offices.

The screenshot shows the 'Sistema Informativo Unificato' interface. At the top, it identifies the user as 'admin (pompei - admin)'. The main content area is titled 'Indici - risultati' and displays a table of search results. The table has the following columns: N., Immagine, Identificativo, Abstract, Progetto, Tipo, Assegnata, Stato, Valid., Ver., and Operazioni. Three results are visible, each with a checkbox and an 'operazioni' button.

N.	Immagine	Identificativo	Abstract	Progetto	Tipo	Assegnata	Stato	Valid.	Ver.	Operazioni
<input type="checkbox"/> 1	immagine non disponibile	NCT: 15-00000149	La Fortuna visiva di Pompei. Archivio di immagini e testi dal XVIII al XIX secolo	ArchivioProgettiScientifici	PRG 1.00		Da assegnare	Si	1	operazioni
<input type="checkbox"/> 2	immagine non disponibile	NCT: 15-00000150	Progetto Pompei in convenzione ARCUS - SAP - SNS	ArchivioProgettiScientifici	PRG 1.00		Da assegnare	Si	1	operazioni
<input type="checkbox"/> 3	immagine non disponibile	NCT: 15-00000001; RVEL: 0	Pompeii Forum Project	ArchivioProgettiScientifici	PRG 1.00		Da assegnare	Si	1	operazioni

Figure 1: Index. Screenshot from the SANP Information System.

Moreover, the System must be designed for helping the promotion of research and exploitation of the Vesuvian archeological patrimony amongst Bodies and people external to the SANP, by providing them with an easy-to-use tool for data storage and interrogation flexible enough to manage information of different kinds, types, formats and structure.

Consequently, the final users of this System have been identified both in users internal to the SANP and in users working for Bodies external to this institution.

On the basis of the analysis of contents and domain, the main requirements of the system have been identified as follows:

- scalability and modularity of the system architecture: this requirement guarantees the durability of the system, by allowing the substitution of single modules without changing the whole system;
- possibility of supporting various formats: this requirement guarantees the ability of the system to integrate various kinds of resources;
- ability of representing complex relations between resources: this requirement guarantees the possibility of creating connections among different data stored in the system;
- adoption of national and international standards: this requirement guarantees the interoperability of resources into the system and with external systems;
- use of open source software: this requirement guarantees the management and maintenance of the system during the time;
- development of a web-based system: this requirement guarantees the implementation of data into the system and

their consultation by users dislocated in various geographic places. This requirement also implies the development of an appropriate users' rights management and of an efficient workflow.

### 3. ARCHITECTURE OF THE SYSTEM

In order to satisfy the requirements on the adoption of standards, on the use of open source software and on the development of a web-based application, the SANP Information System exposes an XHTML interface compliant to the W3C's WCAG standard and has been developed using JAVA technology: Google Web Toolkit (Google Code, GWT, 2008) has been adopted to simplify the deployment of AJAX features. According to the scalability requirement, the System architecture has been designed as a composition of different modules for specific features: data managing, query functionalities, XML import and export of data, repository management, data presentation and communication.

The Apache Tomcat servlet container and the MySQL DBMS have been used during development and testing stages, although virtually any J2EE container and any SQL-compliant DBMS could be employed.

The System is made of three main modules:

1. **AxCore:** the core of the system. It is the JAVA library that offers an interface to the application layer client (web interface). It contains the modules for managing users' rights, cataloguing charts, data, thesauri, vocabularies and authority files. Its features are accessible through five main interfaces:

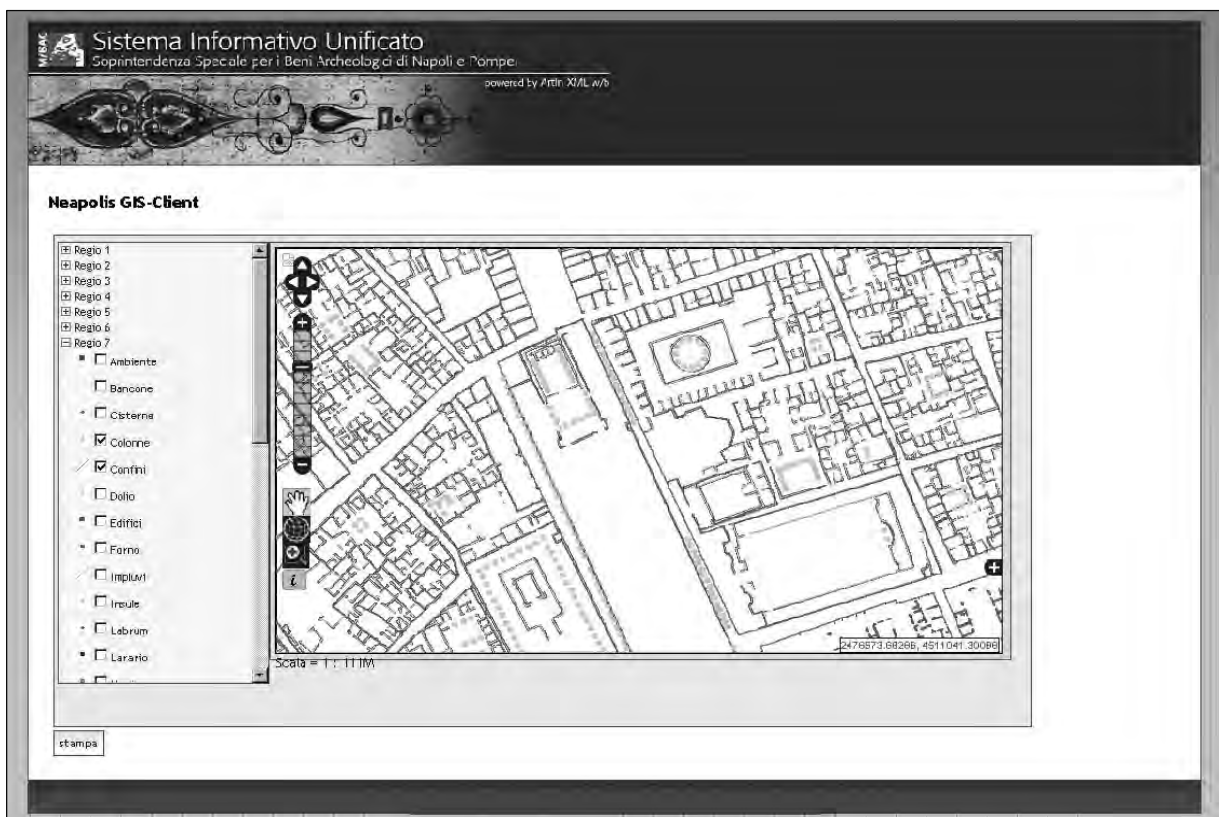


Figure 2: The GIS integrated into the SANP Information System.





#### 4. SYSTEM INTERFACE AND FUNCTIONALITIES

Users access the System through an authentication process: after the log-in, they select one “Project”. Each “Project” defines a working group and a related activity.

Each user can access more than one Project with different “levels” (e.g. one user can have the only-read right in one project and the data-entry right in another project).

The main menu gives access to three main areas: Administration, Search and Browse, Data Entry.

##### 4.1 Administration Area

The Administration area can be accessed only by users owning the right of “administrator”. The sub-menu of this area presents the following pages:

- **Projects administration:** Projects (working group/activity) can be created, modified and deleted here.
- **Users administration:** users can be created, modified and deleted here. All users are associated with their user names, passwords and personal data.
- **Users/Projects connection:** users can be assigned access roles for existing Projects (working groups/activities) here, and be granted set of rights.
- **Levels administration:** Levels can be managed here. A “Level” joins into one profile one or more users’ rights.
- **Import of Charts:** here the administrator can import in the System one, or a group of, cataloguing charts in XML format or in Trc (ICCD format).
- **GIS administration:** here the administrator can upload in the system one or more Shapefiles and can hierarchically order the GIS themes into a tree-shaped structure which will constitute the main menu for allowing users to switch on and off the layers assembled in the themes.

##### 4.2 Search and Browse Area

In this area users can search, browse and view the contents of the Project/s which have been made accessible to them, with the

related “level” (set of rights) and with at least the read-only level. The sub-menu is structured as follows:

- **Simple search:** a Google-like search.
- **Advanced search:** permits to perform transversal searches through the different cataloguing charts schemas, by entering words or sentences in one or more search fields corresponding to Qualified DC terms.
- **Search by field:** allows performing an advanced search among charts with the same metadata schema.
- **Indexes:** displays indexes for each kind of cataloguing chart, authority file and multimedia entity stored in the system.
- **GIS:** gives access to the GIS interface. On the left column it is possible to switch on and off the GIS themes. The buttons contained in the left side of the map allow users to zoom in and out the map, to move into the map using the panning functionality and to perform queries on a given point (by clicking on the “i” button and selecting a point on the map, the system will return the list of all cataloguing charts that are referenced to that point. The exact point will be indicated by a marker on the map.

After performing every kind of search or selecting an index, the interface displays a tree-shaped list in which the resulting types of cataloguing charts, authority files and multimedia entities are listed, flanked by the number of available results.

After selecting a type of content, user will access a list displaying the abstracts of the resulting charts. Each abstract is flanked by a drop-down list that allows the user to perform the operations for which he owns the rights.

Every user will see the options:

- **Navigate:** displays the selected chart and its links with other charts and with the GIS, allowing the user to navigate through the contents of the system.
- **View:** displays the selected record in a PopUp-like window that can be closed.
- **Print:** displays a printable version of the chart.

Users with appropriate access level will be made available the following operations:

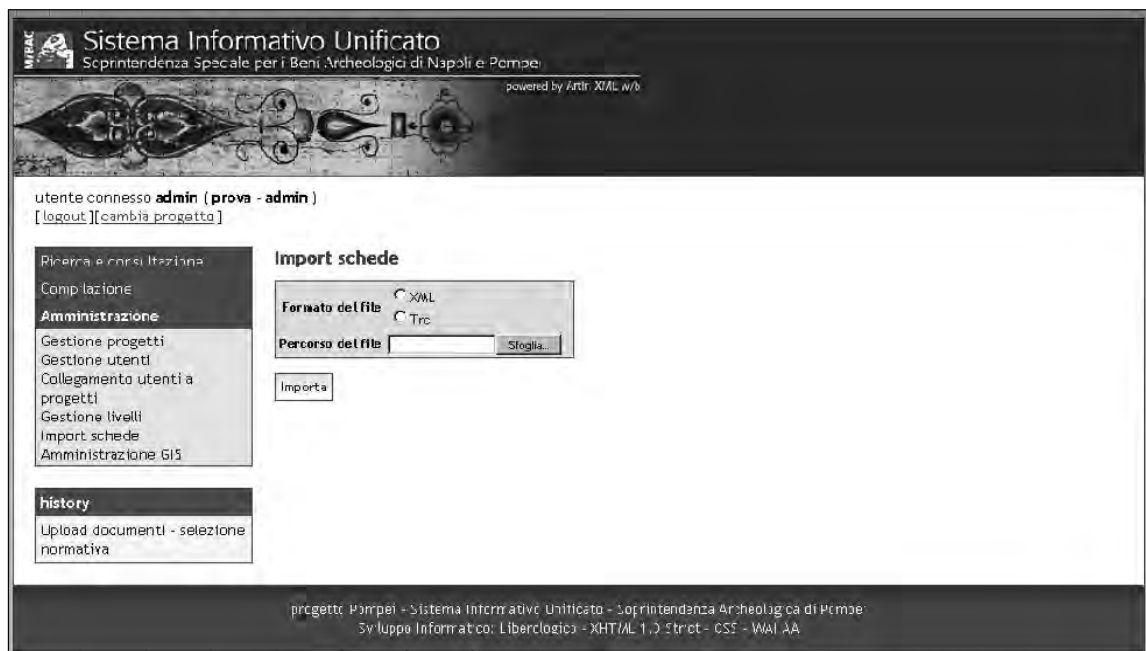


Figure 4: Administration area, Import of charts. Screenshot from the SANP Information System.

- **Modify:** for accessing the chart in the data-entry mode and modifying it.
- **Create a copy:** for creating a copy of the chart, after specifying an identification code for the chart to be created.

Only the users possessing the “administrator” right can select from the list of results one or more items, and press the button “Export”, to export them in XML or Trc format.

The GIS interface displays the map area and a tree-shaped menu on the left. Users can select one or more theme from the menu. They will be immediately displayed. By clicking on the icons in the visualization area, users can: zoom-in and out the map; perform panning; select an area. After selecting an area into the map, the interface displays the list of the resulting charts related to that geographic area.

#### 4.3 Data Entry Area

This area can be accessed by all the users who possess the “data-entry” right for the previously selected Project. The sub-menu displays the options:

- **Data Entry:** the cataloguer selects one type of chart, authority file or multimedia entity and starts entering the data. The data-entry activity is aided by controlled vocabularies and authority files lists. Moreover, it is possible to look up all the values a specific field was filled with, select a value from this list to be used in the current chart, or to perform a “find and replace” operation with a given value into the current chart or in a group of charts. A predefined workflow permits to define the “State” of the chart (“in course of implementation”, “to be approved”, “approved”, etc.). An integrated tool permits the formal and semantic validation of the chart in every moment. The system automatically stores the previous versions of each chart.
- **User Manual:** displays the user manual.

### 5. FUTURE DEVELOPMENTS: THE PORTAL OF THE VESUVIAN ARCHAEOLOGY

A second agreement among ARCUS, SANP and SNS started in May 2007, in order to carry out activities and services for the exploitation and spreading to a broader public of the scientific contents managed by the SANP Information System and resulting from various research projects.

The main product that will result from this second tranche of the project will be the “Portal of the Vesuvian Archaeology”. It will be completed for the end of 2007. The architecture of this Portal integrates four different areas:

**Catalogue:** in this area it will be possible to consult contents deriving from the SANP Information System. They comprehend inter-related cataloguing charts, authority files and multimedia entities. All contents can be related to the GIS. Cataloguing contents will be displayed in a user-friendly visualization: charts will be simplified, avoiding the complicate partition in fields and subfields, and their data will be displayed in a more readable and accessible format.

**2D and 3D GIS:** in this area geographic contents will be displayed and linked with the other resources available into the Portal. For the visualization of geographic contents Google Maps will be used: this solution seems to be more suitable and understandable for web users. By clicking on the map, it will be possible to access: cataloguing resources; digital library resources; CMS contents; 3D models. 3D models will be used

as a 3-dimensional GIS: some measurable and geo-referenced models will be accessible by clicking an icon in the map and displayed through a 3D viewer.

**CMS contents:** a Content Management System will allow for the creation of specific web-pages that will be maintained by various Bodies and Institutions conducting their researches on the archaeological heritage of the Vesuvian Area. The Superintendence itself will use CMS to publish news and articles.

**Digital Library:** edited and unedited texts, images and multimedia resources on the Vesuvian Archaeology will be stored in a Digital Library. Also materials published elsewhere on the web will be referenced here. The analysis identified the open source operating system FEDORA (FEDORA Commons, 2008) as the most suitable for this purpose.

In order to make available those contents through other media, a mobile version of the website will be developed.

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## JOINING ITALIAN INFORMATION SYSTEM FOR NATIONAL ARCHIVES: THE CASE OF RIMINI

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**KEY WORDS:** SIAS, Italian National Archives, Parchments, Digitization

### ABSTRACT:

In 2003 Italian General Direction of Archives took the decision to develop a general information network for all the National Archives: fortunately, the project began to set up from medium or small archives which hadn't received enough attention from this point of view - due to the huge Italian Archival Heritage -, so far. The network called "SIAS" or better "*Sistema Informativo degli Archivi di Stato*" (Information System for National Archives) aimed at making available to users through the Internet - as a first step - a general, but accurate description of all the series preserved in all the National Archives members of the network. Every user from any location all over the world should be able to access the site at <http://www.archivi-sias.it> and retrieve the info which archivists of Italian National Archives published as a standardized archival description for the series by getting data from existing inventories or redacting them from scratch. As the second step SIAS is designed to support the publication of on-line new inventories and some National Archives such as the National Archives of RIMINI reached this second step and went beyond by designing to add even the images of particularly noteworthy documents in terms of aesthetical and/or historical relevance. The idea of this project paper deals with the entire process as seen from a peripheral yet active National Archives as the Archivio di Stato di RIMINI. From the description of general series to the editing of new inventories, from the adoption of international standards (ISAD(G), ISAAR(CPF)) to the implementation of metadata, from the digitization of a large amount of parchments (the so-called "Diplomatico Riminese") and the steps to implement the publication of so many high-resolution pictures, but also the impact the project once it will be completed will have onto users and people who work at the National Archives and namely the reactions of common archives users.

### 1. INTRODUCTION OR WHAT SIAS IS

Since we'll be talking about "*Sistema Informativo degli Archivi di Stato*" referring to it just as SIAS, let's try to explain how this "Information System for National Archives" is intended to work. SIAS has been designed to manage all information about Italian National Archives and to work as a distributed application, residing on a website located at <http://www.archivi-sias.it>.



Figure 1: Home page of <http://www.archivi-sias.it>

After a beta-testing period, once adopted by Ministry of National Heritage and Culture Activities in 2003 for the whole Italian Administration of Archives, it has begun to deal with all the information published by every National Archives onto the website thanks to a client application called Archivist

Amanuense since 2004. That version of SIAS application is based on ASP 3.x technology and uses MS SQL Server as a database.

Without going into details and leaving out the whole description of the deep structure of the database with all its tables and relations, the basic idea of SIAS as a network of archival information is distinguishing three informational general patterns: information about archives as physical repositories and public institutions ("complessi documentari"); information about producers of the archival documentation ("soggetti produttori"); information about the archival fonds themselves through published or existing inventories ("strumenti di ricerca"). Of course, the standards beneath are ISAD (G) and ISAAR (CPF).

Obviously, the three tiers are strictly connected to each other so that given a National Archives it's possible to access to all the fonds kept by it and given a series or a document kept by a National Archives it is possible to retrieve all the authority records related to it. In any case, all the three areas can work as starting points. Full-text research is always possible.

From the adoption of the SIAS on the National Archives who joined the project began publishing their descriptive records. As a first step, they were required to just share descriptions of documentary series getting that kind of information normally from existing traditional (paper) inventories. It has been a sort of pioneering stage in which the possibilities of SIAS have just been tested. Naturally, that's only a first help to users. By consulting the SIAS website, they would have a rather precise if not detailed idea to which archives to go to get the documents

they need for their researches. Given the historically huge richness in scope and content of Italian documentary heritage, that's already a great point to know which National Archives should be visited and to know which documents could relate to the research subject or the field of interest of users.

Once the first stage was concluded, most of Archives passed to the second one. Now, the Archives are required to publish much more detailed records either converting into electronic inventories existing paper inventories or creating totally new inventories for fonds which hadn't yet described. That has been a very exciting challenge especially for small Archives as the National Archives of Rimini which kept a considerable amount of documentation never described before except for brief high-level accounts of content. And naturally, one of the goals of the project was to discover "hidden treasures" faithful to the idea that a documentary complex without an inventory is actually unattainable so that it can be truly hidden or even nonexistent. Besides, it's often observed in the practical life of archives that after a document has been described, it becomes interesting for users reaching a status of relevancy it had never enjoyed before.

## 2. NATIONAL ARCHIVES OF RIMINI AND SIAS

Also before SIAS was implemented there were some really interesting experiences in the field of information retrieval and digitization in Italian Archives. Of course, all those were about great Archives such as *Archivio di Stato di FIRENZE*, *Archivio di Stato di ROMA*, *Archivio di Stato di BOLOGNA*, *Archivio di Stato di VENEZIA* among others. Each of them developed its own system and adopted rather sophisticated and advanced technologies and pathed the way for any of the following experiences. Now, initially SIAS was aimed at smaller or simply less famous archives all around Italy; the ones which hadn't yet accomplished the task of getting their own systems and what was new about it was that a one and unique system for all Italian archives was being implemented.

That's why *Archivio di Stato di RIMINI* ("National Archives of RIMINI") has seen joining the SIAS project as a great opportunity for self-promoting, attracting financial support in the first place, but also and first of all for making publicly disposable its inventories which – as often happens to young and not so great archives – hadn't been got the due attention.

According to Italian Archival Law, every capital of province has its own National Archives. Since Rimini was raised to the status of provincial capital only in 1995, the National Archives of Rimini has been set up only in 1999. Of course, a separate section of National Archives of Forlì had existed in Rimini since the beginning of the Seventies without any form of autonomy. Since then, National Archives of Rimini has been keeping as its largest archival fonds the documents of the Municipality of Rimini (*Comune di RIMINI*). As a city Rimini can boast a long history and reached its highest importance and relevance in XVth century under the rule of the family of Malatesti. That's why the archives of the municipality are actually the most important ones in Rimini so far. In particular, a large collection of ca. 5000 parchments dating from XI to XVIII century, assembled in XIX century at the Gambalunga Library from a group of scholars, could be considered as a true treasure for the historians of the city.

From the beginning these are the specific goals have been set for the National Archives of RIMINI: the exploitation of this

legacy and the description and ordering of the largest part of the documentation kept. So that, it's not accidental that a particular attention has been directed to the fonds of Municipality, to the so-called "Diplomatico Riminese" (the complete collection of parchments) and to fonds that had never been described before (like *Ospedale di RIMINI* ("Hospital of RIMINI")).

To perform the heavy task of describing all the series (and after them all the documents) the National Archives took advantage of the collaboration of three external researchers.



Figure 2: Archivio di Stato di RIMINI

In 2005, the first stage (simple description of series and producers) was completed so that since then users have been able to get a reasonably full and detailed list of the fonds and their series kept by the Archives of RIMINI. It is interesting to notice that at that point the whole structure of the National Archives emerged. It's always relevant in describing a documentary complex to duly formalize the context. As we say in archives: *context is all*. That is context is an essential part of the meaning of a document and the structure itself of a fonds is a meaningful element of that context which can't be disregarded in any case. Any good application for archival description should be enough powerful to give a representation of the context and the complex hierarchies which can exist between any document and another.

Fortunately, the structure of SIAS is enough flexible - on both server and client side - to give account not only of context, but also to describe papers as well as seals and even parchments with all their complexities and richness and reveal the hierarchical relationships between all these elements.

An interesting module, which is just present in a draft version so far, is about managing authority records: it should allow to produce a data base of all the names of places, persons, institutions involved in the documents as the producers of these and/or cited in the documents themselves. Common users generally refer to and search for documents by using as main keywords this kind of information. Besides, a correct management of authority records could common to all the National Archives, resulting into the first step of a shared form of inventories. National Archives would be allowed to exchange these data each other, making so easier to edit inventories.

### 3. POPULATING THE SYSTEM: ON-LINE INVENTORIES



Figure 3: A list of inventories

In the second stage, the National Archives of RIMINI coped with the challenge of describing a large number of fonds which never were described before. One of them has been for example the E. C. A. – Ente Comunale di Assistenza (Municipal Board of Social Security).



Figura 4: Online inventories for Archivio di Stato di RIMINI

It is in this stage that SIAS application could show all its potentiality as a descriptive kit for archivists. A long list of new inventories has been added to the web site of SIAS. When a fonds has its inventory accessible on line it's marked with a red icon [INV. ONLINE]. Clicking on that the whole inventory is consultable on line as a expandable or collapsible tree.

In the long list of the new inventories the *Municipality of RIMINI*, the *Civil Engineers*, the *Fascist National Party* (with the pictures included), the *Cadastre*, the *Congregations for Charity*, *Notaries of RIMINI* and some other “minor” archives included some collections of papers assembled by scholars in XIX century. In particular, the *Municipality of RIMINI* underwent a deep rearrangement both in physical and in descriptive terms. That action has allowed to detach some documents (such as a small fonds relating to another Municipality: *Mercatello*) and distinguish the two macro-series of the pre- and post-unitarian documents (before and after 1860,

year of the unification of Italy under the Savoy dynasty). It's noteworthy that the total number of records created exceeded 10,000.

### 4. AN IMPORTANT EXTENSION OF THE SYSTEM: PARCHMENTS

From the beginnings, SIAS was imagined for delivering not only information about documents, but also the documents themselves or better, of course, digital copies of them: especially rare and/or valuable documents. Apart from the pilot projects and testing provided by *Archivio di Stato di PALERMO*, a lot of experiences were made both in libraries and archives all around the world. For instance, *Archivio di Stato di FIRENZE* allows users consulting some important fonds through a web interface. *Archivio di Stato di BOLOGNA* allows user to see *Liber Paradisus* online through a really functional interface.



Figure 5: A parchment about Republic of San Marino

In 2006 the National Archives of Rimini planned and achieved the scanning of all the ca. 5000 parchments of *Diplomatico Riminese* fonds. That implied the uploading not only of the descriptions of the documents, but also of a copy of the document itself. To achieve this goal National Archives availed itself of the work of RecordData srl, a firm specialized in this kind of jobs. Of course, it implied a noticeable effort by the part of relatively small National Archives and the financial support of the Foundation of the Cassa di Risparmio di RIMINI. The pictures have been taken in high resolution and any of them is several megabytes huge so that only a lighter version (in JPEG format) will be uploaded onto the web site. The result of the digitization is stored in two external hard disks, one of them will be disposable for users at the National Archives and in up to 77 DVDs. Any parchment has been digitized into high-resolution images: front and back; and additional images in TIFF format at a lower resolution. Also a much lighter picture in JPEG format has been produced in order to publish it on the web site.

The quality of these pictures is so high that for any practical usage they can substitute the originals. This results into very huge files (almost 80 megabytes). Using the copies instead of the originals prevent them from being damaged or consumed by users, as the parchments are among the documents most requested by users and historically among the most important documents kept by National Archives of RIMINI.



Figure 6: Parchment with seal.

After all, the parchment collection now fully digitised of Archivio di Stato di RIMINI could be considered together with Biblioteca Malatestiana di CESENA for Memory of the World project of UNESCO. It's unthinkable to write the history of Malatesta family without accessing this fundamental source.

But also users from outside the National Archives of RIMINI will be able to consult the parchments on the site of SIAS. Although the copies uploaded will be of less quality, their quality will be enough high to be read and studied on line altogether with their precise and accurate description and the links to the records of places, names, persons, institutions cited in the texts or the links to the descriptions of the producers of the document and eventually the summary (both newly written and written by a XIX-century scholar).

The connection between any picture and its archival description is provided by its "MAGs" (*Metadati Amministrativi e Gestionali* = Managing and Administrative MetaData). SIAS is able to manage all these metadata (XML files) and to provide a general schema on which the firm which took the pictures could model their meta-description. It's important to associate to any file of an image the right XML file of its MAGs.

The uploading of the pictures will take some time. It's noteworthy that so far the series of high-resolution images waiting to be added to SIAS is the first of a complete fonds and the first of such a high number of files: 5,000. The previous uploadings have been mainly experimental and of up to 100-200 pictures as a maximum. Also, the server which hosts SIAS could be exceedingly stressed by that amount of files and possibly by a certain number of real users.

A good point in the design of SIAS is that it's modular. After the descriptive part, the module about seals and the module about parchments have been added, at the same time, maintaining the coherence of the system. The principle of uploading not only the description of a document, but also the document itself could be applied to other documentary series.

## 5. A PROJECT FOR ANCIENT CADASTRES

In 2008 the Province of RIMINI as a part of its project "SITUA" ("Sistema Informativo Territoriale Urbanistico Ambientale" della Provincia di Rimini: <http://www.provincia.rimini.it/territorio/situa/>) has produced and completed the digitization of all the maps of the Cadastre called "CALINDRI" from the land-surveyor Serafino CALINDRI, who drew the maps (1762-1774).

As the images have been digitized for different purposes and by a different firm, the digital images still lack of their MAGs. Also in this case, the copies will substitute the originals in the consulting room and these maps have already damaged partly by users through their intense usage. Due to the fact that often they are consulted by surveyors it will be useful to have a digital copy of the maps in a raster format, which could be used as a basis for a vector re-elaboration. This can be interesting in a wide range of cases: from research in the history of territory of the province of RIMINI to archaeological researches and interactive re-elaborations.



Figure 7: A map of Calindri cadastre.

Although it is not yet clear till now how this sort of files could be integrated into the system, there are a lot of possible usages. The National Archives of RIMINI is studying the possibility of installing a GIS (*Geographic(al) Information System*) workstation made available to users and scholars. Anyway, the only acquisition of maps couldn't be so much significant without the acquisition of the other information normally registered into a cadastre like the ownership data and so on.

In any case, documents of this kind remain among the most requested by users and could be considered – once digitised – for EDLocal (EuropeanaLocal) as a step in preservation of European/Local cultural heritage (Social Life area).



## 6. IDEAS FOR ACQUIRING GENERAL REGISTER OFFICE RECORDS

Another project under study is the digitisation of the General Register Office. It's a fact a large number of requests of genealogical data is made almost every day to National Archives. In 2004-2005 the Genealogical Society of Utah microfilmed the whole series of registries which had been kept by Tribunal of RIMINI. It included the data of 20 municipalities (*Comuni*) of the Province of RIMINI from 1866 to our days. Unfortunately, such an important job was performed producing analogical microfilm so that all should be now converted into a digital format. Of course, there will be the problem to associate the images to a genealogical record, possibly using the GEDCOM standard.

Of course, that's a module (the genealogical) which hasn't yet developed at all. So, there's no idea of when, how or even if it is ever developed. Anyway, the first step is to make accessible at least images of the registries through the digitisation of microfilms. As in the case of the parchments, the main part of the job will transcribe the data from the documents.

For these documents, too, once digitised and described, should be considered the opportunity of making them public through the Europeana website.

## 7. ON USERS' SIDE

A question which naturally arises when examining systems like SIAS is whether these applications impact positively or not on users. A first reaction of users when told they can do their researches starting from a web site is of mistrust. Users are to be taught to take advantage of this new way of retrieving information about their topics. One even stranger reaction can be noticed especially on the part of *aficionados* of archives is expressed normally by the sentence "nothing can be found any longer", which is obviously the exact contrary of what the archivists think. The idea is to offer the chance of finding much more. So, the archivists are really puzzled, when they get that feedback by users. The fact is that any new procedure has to be learnt and some users are particularly reluctant to learn, since they've always made their researches naturally in another way. They don't seem eager to give up to their habits.



Figure 8: Reading room of Archivio di Stato di RIMINI

That's why in general SIAS should consider to take into greater consideration the usages and opinions of normal, non-technical users. It could be foreseen a module of management of users and the creation of a database of typical informational behaviours of users and their attitudes towards historical documentation. Also, typical researches and a list of keywords could be stored into the system to help future users who could try the same research. In a few words, it would be useful to foresee a much more user-biased system than the one of today.

Now, users and in particular researchers and scholars are an asset for National Archives. It shouldn't come as a surprise, if they could add their works to the document they're studying and, once approved by archivists, upload them. For instance, they could add a regist or a transcription of a parchment. That's why a solid and advanced user management system is to be activated.

## 8. A NEW SIAS?

SIAS, of which the current version is 4.0.0.2, is clearly – as we know it – to undergo some sort of more or less radical revision. A lot depends on the success itself of the system. As long as most National Archives join the SIAS and begin uploading either electronic inventories or digitised documents, the system has considerably to improve its performances and functions.

Actually, a general reengineering of the software has been announced. That's not yet clear the direction this reengineering process will take. As to now, it's been already decided the site itself will be hosted by CASPUR (<http://www.caspur.it>), a university consortium for supercomputing, which has been charged with rewriting the code in order to meet the demands of the National Archives, which have used the system, the most, so far. For instance, it's quite obvious the multilingual dimension of the project will be fully developed.

Anyway, it appears some suggestions for further developments can be given by National Archives users based on every-day experiences.

First of all, it would be useful software could be open-source, avoiding some problems of distribution that partially plagued a high-scale adoption and usage of the system. A PHP/MySQL solution would be greatly appreciated. A clearly documented and public structure of the database would be appreciated as much. It would allow any single Archives to participate in the development or to sketch single small applications to feed local or specific needs.

One of the most needed feature is a simple and effective client application to update inventories, finding aids and files uploaded by any single Archives. It should be at the same time a tool for describing archival fonds and to upload them to the website. It would be better if it were written in the style of an interactive web application (for instance, using AJAX): that could allow archivists to expand, maintain and update documents published on the website from everywhere. Related to this, there's a general demand on the part of most users for a more friendly interface.

One more feature broadly needed is the integration between SIAS and a Content Management System (CMS), especially "Archivio&Web" the CMS Italian Ministry of Culture is developing accordingly the directives and specifications of

MINERVA+ Project. All National Archives which will use Archivio&Web to build their own websites shall have the opportunity to show directly on their sites their part of SIAS: as if it were hosted there. What else is the main “content” of archives but archival fonds? Besides, all other contents on the site could be linked directly to the documents, if needed.

Integration with MICHAEL+ is also requested. There’s to say archival data are already accessible through MICHAEL+ website, but normally single archives don’t have any control on this form of publication of data. In order to publish a set of data on MICHAEL+ website it’s necessary to get through the General Direction for Archives.

It would be particularly interesting to imagine a similar extension to link directly digital images (for instance, parchments, public registries or maps) to EDLocal/EuropeanaLocal repository and also through a back office application to manage these links.

Anyway, the most urgent part of the system to be developed is an *image organizer* (one could even think of something in the *Flickr* style). It seems useless to upload digital images, if there’s no suitable tool for browsing and/or downloading them, tagging them or adding bibliography, references, scholars’ notes, comments and so on. Since one of the points of SIAS is that it has to perform the task of delivering both information about archives and the documents themselves, this section should be considered the heart of the whole system.

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## ONLINE ACCESS TO DIGITAL COLLECTIONS – DESIGN AND USE OF MUSEUM DATABASES

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**KEY WORDS:** Museums websites, collections information, online databases, evaluation of web usage

### ABSTRACT:

The creation of institutional websites is one of the most widespread information and communication technologies in the cultural sector. Expectations of web users, together with social and technological developments, have influenced an expanding trend among cultural organisations to offer wider inclusion and greater versatility in the presentation of collections and related information in their digital spaces. However, the effectiveness of these applications has not been systematically tested so far, nor has their use been examined with any in-depth research study, despite the increasing pressure on museums to provide online access to their collection catalogues. This paper will present the results of a research project which aims to address this gap. At the first stage of the research, museum websites from different countries were selected and analysed. After the identification of specific groups based on the type of web presentation, the research project focused on the museums that presented digital databases of their collection on their website, sending them a questionnaire on the design of the databases and of their use by virtual visitors. This paper will present mainly the results from these first two stages of the research and will place them in a broader discussion about the use of cultural information by different users in various contexts.

### 1. INTRODUCTION

The impact of Information and Communication Technologies (ICT) in the cultural domain should be carefully examined, because these tools have changed the panorama of the sector regarding, among others, the learning and communication of cultural contents. The adaptation of ICT to the necessities of the cultural sector has increased during recent times, partly influenced by the need for a higher degree of competitiveness in a more global market, reflected by recent political strategic documents, such as the report from the Lisbon European Council of 2003. Several cultural institutions, aware of the importance that ICT are acquiring, have been implementing innovative technological applications and experimenting with new ways of communicating and presenting digital cultural assets. Moreover, technological innovation has gone beyond the initial economic benefit-oriented trend of competitiveness and has reached a more complex stage, where impacts on social, cultural and political spheres underline the empowerment possibilities of ICT.

However, the implementation of innovative cultural applications is quite often carried out by cultural agents and content generators without paying sufficient attention to the actual ways that users interact with them, but by merely applying the available technologies to traditional museum practices. This does not take advantage of the potential of information society, which provides museums with tools to avoid mere electronic reproductions of the actual content, allowing them to add value to exhibitions, presenting complementary information that otherwise would not be available for users. This content management process implies important changes in the practices of storage, conservation and preservation, but above all of diffusion and communication of cultural content, making it theoretically more accessible to a broader public and ideally, to the whole of society. It is in this context that cultural institutions make use of technological innovations (each to a different extent and following its

individual strategy), creating their own websites, digital collections and virtual exhibitions.

The present paper deals with the results of a research project investigating the design and use of online museum collections information. After a brief theoretical overview of the key issues, the paper will present the methodology, as well as the main findings of the research. Finally, some conclusions will be highlighted and further steps described.

### 2. THE CHANGING PARADIGM OF MUSEUM COMMUNICATION

Museums' widely recognised role of communicating contents to diverse audiences has evolved considerably over the last decades. Until quite recently, this communication was based on a linear, unidirectional communication model, where the only actors were the curator (as transmitter of the content) and the visitor (as recipient of that content).

Recent developments in museums and museology, however, have transformed this traditional communication paradigm into a more complex one, where emphasis is placed on the construction of meaning according to the visitors' personal context. ICT have played a very important role in this direction, facilitating a more continuous and flexible process where individuals can adapt the message to their personal context. Communication is now seen as a process where messages are constructed and interpreted differently according to the circumstances of the recipient. This constructivist communication paradigm influences also the diverse models of presenting content to museum audiences in the digital space of the institution.

Following these ideas, we can distinguish two main models of providing access to contents to the digital visitor.

- Access to information. This refers to making museum information available to everyone. So the main processes of this perspective can be identified as the provision of multilingual content or the availability of digitized content. Following this model, museums ‘transpose’ basic information, the raw data about their collections making them available to the broad public, but with no further elaboration.
- Access to knowledge. This goes one step beyond the previous approach. After making information available to users, institutions try to also provide complementary ‘information’, approaches or tools to help them unlock the meaning behind cultural content. These can range from contextualization of the content (e.g. facts and information about the context in which the object was created or about the meaning of the object itself) or links to other related content to more dynamic and participative processes, where the user is supposed to acquire related knowledge by actively interacting with the content itself.

These approaches affect the way cultural institutions design their websites and grant different types of access to their collections and catalogue information.

### 3. NEW TECHNOLOGIES AND MUSEUMS

The deep transformation of the cultural sector that implies the implementation of ICT has impelled museums to face new challenges in four main areas: passing on of information and knowledge; global access to Cultural Heritage; preservation of cultural assets; and more efficient cultural research (Artnouveau, 2003). Appropriate use of ICT applications in museums needs to take into account the complexity of roles of these institutions as agents for preservation of cultural heritage, managers of cultural content and providers of cultural services. Consequently, an appropriate model for technology implementation in museums should embrace all the stages related to the cultural value chain, as well as to the operation management systems.

The creation of digital spaces of museums has posed a great challenge for these institutions. The incorporation of these environments to the cultural realm will never lead to the disappearance of the actual museums as was initially feared, but should be viewed instead as an opportunity to broaden their audiences, making their contents available to everyone and complementing physical activities. In fact, as some authors state, the presence of a virtual version of the museum can encourage some people to visit the actual museum, as they often only find out about it after discovering its digital version (Bowen, 2000).

### 4. RESEARCH PROJECT ON THE USE OF ONLINE MUSEUM COLLECTIONS

Although museum online collections have multiplied over the last two decades, studies about their real use by end users remain very limited. Some studies have dealt with usability and accessibility issues or with patterns of use of the websites as a whole (Loran Gili, 2002; Kravchyna and Hastings, 2002), but no study has analyzed in depth the use of the digital content presented in the website. The few studies available (mainly from the Anglo-Saxon world) deal with general information, such as the number of users of websites, their paths of visit or

even their general pattern of visit (duration, number of pages, day and time of visit, and so on).

The present research project aims at identifying a clearer and more complete picture of the behaviours and patterns in the use of online museum collections by virtual visitors. The objective is to study the real use of these digital collections, identifying who uses that kind of content, the purpose of use and some patterns of behaviour concerning the specific use of the digital collections and their databases.

Stemming from theoretical conceptualizations based on the literature about the use of technology in museums (Artnouveau, 2003; Loran Gili, 2002; Kravchyna and Hastings, 2002), we can identify some structures were most of the institutional websites fit. These are mainly related to three different categories:

The first big category, and the most common one among museum websites, is the customer relationship one. In this category institutions cultivate their relationship with the potential customers, giving them information about the institution, its activities or even, in the most complete cases, some ways to send their opinion or feedback.

On the other hand, the eMarketing category will be translated into museum websites with virtual shops. In these shops, customers can purchase items related to the institution, which will be delivered either digitally (images, articles, eBooks or digital reproductions of the cultural assets) or physically (souvenirs, books, reproductions and so on).

The last main category is the one dealing with the contents of the institution. In this case, information about the digitized objects is usually available to the user in the collection(s) section of the website, containing sometimes also some kind of educational resources that will reinforce or support the learning process of the end user. Our research project has dealt with the contents of the institution and the way these are presented to virtual visitors within this category.

#### Research methodology

The first step taken during the research has been the identification of different models of presentation of museum collections and digital catalogues. Towards this end we carried out an empirical evaluation of museum websites supported by a previous literature review.

For the definition of the sample for the analysis we used the Virtual Library of Museums (VLM) of ICOM. This website was created and is still maintained by Prof. Jonathan Bowen, helped by Prof. John Burke of the Oakland Museum of California for the USA section of the site. A few years after its initial creation, ICOM started to support the site. The VLM links to the websites of museums all over the world. The entries that appear on the VLM are sent voluntarily by the museum staff filling one simple web form, with slight variations according to the origin of the institution.

Linguistic and time constraints have limited our initial analysis to museums from Spain, the United Kingdom, Germany, Greece and the USA. Except the case of the USA, in the rest of the countries, the museums analyzed were all the ones that appear in the VLM list. Regarding the American ones, however, because of the large number of museums we determined that the analysed sample would include only art and history museums. The total amount of museum websites analyzed was 1921 and it

can be divided as follows: USA 955, United Kingdom 518, Germany 299, Spain 138 and Greece 11\*.

After the analysis, some of the cases were disregarded from further analysis because a) the website did not work or was under construction; or b) the website did not fulfil the minimum requirements for the analysis. For a more accurate analysis, only those websites presenting at least some highlights of the collection with some minimum data about them have been taken into account. For example, those websites which only have a paragraph describing the collection or only a few photographs have not been included in the analysis. In the end, the final sample studied in greater depth consisted of 219 entries.

	VLM websites number	Websites with online collections	Percentage
USA	955	110	11,5%
United Kingdom	518	56	10,8%
Germany	299	20	6,7%
Spain	138	31	22,5%
Greece	11	2	18,2%

Table 1. Websites number by country listed in the VLM and percentage of those presenting some kind of online collection.

After the analysis of the websites, the second stage of the research has been carried out through qualitative analysis using a questionnaire sent to a specific subgroup of museums. The questionnaire dealt with issues related to the design and use of the databases.

### Definitions adopted for the analysis

There are some key terms for this research that should be defined.

The difference between highlights and collections lies on the fact that, while highlights only present a selection made by the institution of a part (usually quite small) of the museum holdings, collections on the other hand, are quite representative and embrace, if not the whole collection, at least a big part of it. These two terms do not refer to the type of presentation, but only deal with the proportion of the collection presented on the website.

On the other hand, when we talk about catalogues and databases, there is a clear distinction between them. Catalogues have a browsable character, that is, they mainly present different areas, sections or groupings of the collection and the visitor can access the objects by browsing within these categories through web links. Databases, on the other hand, have a searchable character, enabling visitors to access the content they are looking for in a more targeted way by making use of search terms.

It is therefore important to also take into account if the website has some kind of searching tool and the level of search it supports. In our analysis we differentiated three main types of searching tools: The first one is the *simple* searching tool that supports searches using single terms (one at a time). The

*advanced* search, on the other hand, is a little bit more complex than the simple one and enables the combination of various search terms (either free text or selected from predefined lists) in order to obtain more accurate results. In most cases, this second kind of searching tool allows users to also perform simple searches. Finally, the third type is the *complex* searching tool which is the one designed for expert users and supports more technical or specialized scientific terms (one example is the searching tool of the database of the Museum of Archaeology and Anthropology of the University of Cambridge). We observed that several museums do not have one exclusive type of searching tool, but a combination of them, which we characterized in the study as *combined* searching tool.

Concerning the presentation of the content, we used the following terms and categories in the analysis of the results. *Labels* are the digital equivalent of the physical labels of the actual collections. Under this category we considered the brief informative notes and phrases presenting the main facts about the object, usually related to its identity. More complete than those labels are the options of explanatory texts, creator details and contextualization of the object. *Explanatory texts* offer in greater depth details about the object (such as technique, composition, topic, and so on), while *creator details* present information about the artist or the person or group who created the object. Finally, the *contextualization category* refers to the information about the context (historical, social, artistic, etc.) in which the object was created or to more specific contextual information about the topic that the object is dealing with. For example, if the website includes the painting “The Oath of the Horatii” of Jacques Louis David, some form of contextualization might be information about the history of those three brothers or about social, historical or artistic aspects of the French Revolution, period of the creation of the artwork.

## 5. RESEARCH FINDINGS

The initial results of the first stage website analysis have been presented in more detail in another publication (Gil & Economou, 2008). In this paper we will focus: a) on the results related to the groups of museum websites identified, and b) on the qualitative analysis of the questionnaire sent to a selection of these museums (those belonging to the second main group).

### Grouping of museum websites studied

The analysis of the results showed that we can distinguish different groupings among the museum websites we examined. First of all, two main groups were identified according to the presence or absence of an advanced searching tool on the site.

The first group is the one with no searching tool or a simple one. Museum websites under this group include browsable catalogues of either only the highlights of their holdings (subgroup 1a) or the entire collection or large parts of it (subgroup 1b). The presentation of the contents in both subgroups tends to be quite simple, with images, labels and, to a lower degree, explanatory texts.

The second group is the one providing advanced, complex or combined searching tools. Museums in this group provide some form of an online database of their collection and also some form of a browsable catalogue. The contents tend to be more elaborate with images, labels, explanatory texts, creator details and zooming options. Within this group, we can also identify another two different subgroups:

\* The latter includes the webportal of the Hellenic Ministry of Culture, which links to a large number of public museums, as well as private collections in Greece.

- Group 2a: This subgroup includes websites with mainly digital databases and in some cases also browsable catalogues. The presentation of contents presents a slightly higher degree of complexity with creator details and zooming options. However, the presence of collection highlights is quite low.
- Group 2b: Finally, this group is the most complex one. It uses browsable catalogues and digital databases to present highlights, as well as the whole of the collection. Websites in the group offer the possibility of a simple browse or a deeper search of the contents. Similarly, the presentation of the contents is also the most complex one, because it embraces from the most simple images and labels to more elaborate links to related works and contextualization of the objects.

Groups identified (type of collection presentation)	Num. of museums	Percentage
Group 1a (no search, highlights only)	44	20,1%
Group 1b (no search, entire or most of collection)	77	35,6%
Group 2a (search tool, database, maybe also browsable catalogue)	52	23,7%
Group 2b (search tool, database & browsable catalogue, complex presentation)	34	15,5%
Non classifiable	12	5,5%

Table 2. Number and percentage of websites corresponding to each group.

For the second stage of our research, we send via e-mail a questionnaire to the 86 museums belonging in the last two subgroups, 2a and 2b, for a more in-depth study of the design of the online databases and their use by end users (as recorded by museum staff). In most cases, the staff contacted or who send the final response were IT officers, webmasters, curators, collection managers or directors. We have received so far a response from 22 of these museums.

#### **Qualitative analysis of the questionnaire: museum responses about the design and use of their online databases and catalogues**

The analysis of the questionnaire responses has shown some interesting facts about the design of the online museum databases. First of all, there is great variety in the length of time that each institution has been providing access to an online database on its website. In general, this period ranges from around 2-4 or 6-8 years with the lowest being 1 year and the highest 11 years.

Regarding the different databases used, the dispersion is quite wide, because only Oracle, AdLib, KE Emu and MySql are used by more than one institution, while the remaining are used only by one (Micromusee, Voyager, Past Perfect, Multimimsy, Mobius, Modes, ContentDM and Index+).

Most of the museums which responded collect some kind of information about their virtual users, while those which do not, stated that this is because they are not capable of doing it or because the application they use does not enable them to do it. The way that museums collect usage information is really diverse and does not show any trend, because each institution uses its own program (such as Urchin, Webalizer, Google

Analytics, and so on). Moreover, the information collected does not present any clear trend, because each institution collects very diverse data. The most frequently collected data relates to general information, page views or number of visits, according to the needs of the institution. This fact can also hinder potential comparisons of trends and user behaviour.

In relation to web users' responses, the institutions participating in the survey tend to receive quite diverse e-mails and queries. These are, principally, related to general information about the institution, information about the collections, general feedback or comments about the institution or the website, requests of images, actual books, etc. or requests for technical assistance when consulting the online collections or the databases. The profile of the users is relatively well defined and relates mainly to researchers, students or academics, while the general public or schools contact the museums less frequently. Moreover, the users who contact the museums tend to be from the same country where the institution is located, except from the cases where users have some link to the exhibited content (such as people from Israel contacting Jewish Museums).

Finally, when asked about lessons learnt so far from their experience of providing online access to their collections database(s), museum staff remarked upon some initial problems that needed to be addressed. These are related to database errors, the need to clarify the way users should search into the database, an increasing need for more information to be made available or even for more customized information to fulfil different user expectations. However, museums also highlighted some really positive aspects, such as the appreciation by the users of the availability of the information or the increase of the number of virtual visitors, as well as the new possibilities for interaction between institutions due to the easily accessible information. Some museums identified also the need to know more about the real interaction of users with the collections and the databases and stated that this is an important gap that should be addressed immediately.

## **6. CONCLUSIONS AND FURTHER IMPLICATIONS**

Most contemporary museums have been trying to keep up with the reality of their time. One of the more recent readjustments has been the use of technologically innovative applications to address the needs and expectations of users. According to the different web technologies implemented, museums present diverse models of making information and knowledge available to users. This paper has presented the initial findings of a research project that explores the different ways that online museum collections and databases have been designed and are being used.

The diverse features present on the institutional websites of the museums we studied allowed us to identify some different groups. These can be ranked from the simplest one with browsable highlights and some basic information about the collections to the most complex ones with collection databases that allow different degrees of searching and provide more in depth, precise and contextualized information about each object.

The second stage of the research has focused on the museums belonging to the more advanced group providing searchable databases. The qualitative analysis of the questionnaire sent to the staff of these museums has highlighted different facts. Every museum follows its own pattern related to the design of the database and the collection of information about its virtual

users, with no possibility of identifying a clear common trend. This may prove a handicap for potential future collaboration among institutions, because technical incompatibilities can arise from the use of different programs, even though the most important aspect is the structure of the data. Similarly, the collection of different types of user information by museums does not help to compare user profiles or trends of use, because of the variety of the data collected.

Although the nature of user e-mails and queries received by the institutions is quite diverse, the profile of these users is in most cases similar. Queries usually come from academics, researchers or students from the same country of the institution. However, some museums do not collect any information about the virtual visitors themselves.

Just as some museums have identified, what remains to be carried out now at the next stage of our research is the systematic study of the real use of the online museum collections by their virtual visitors. This will include both the quantitative analysis of web logs from specific case studies, together with qualitative evaluation with target user groups. This analysis should help us find out more about the way the important and resource-intensive tools are used, enabling museums to closer meet user needs, as well as address issues related to the process of curating online collections.

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# COLLECTION DESCRIPTION IN THE EUROPEAN INFORMATION LANDSCAPE: MICHAEL THE MULTILINGUAL INVENTORY OF CULTURAL HERITAGE IN EUROPE

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**KEYWORDS:** Collection Description, Cultural Heritage, Multilingualism, Terminology, European Digital Library, MICHAEL

## ABSTRACT:

European countries have invested significantly in digitization programmes and the results are transforming access to cultural content. The digital content is distributed across Europe in institutional repositories and made available to the public through institutional websites. Recent years have seen a number of initiatives to harvest item level metadata from institutions to create regional, national and European access points. At the same time there have been initiatives to establish registries of collection and service descriptions. This paper describes the evolution of a Europe-wide project to catalogue digital contents at collection level into MICHAEL (the Multilingual Inventory of Cultural Heritage in Europe). In the multilingual European context, the harvesting of collection description metadata has presented the MICHAEL project with practical issues that have been addressed in order to provide users with simple, easy-to-use multilingual interfaces. For its human users, the MICHAEL European service provides useful information to access quality-assured digital cultural contents. MICHAEL services are also being harvested by machine services to provide joined-up information services which integrate both collection-level and item-level metadata. This paper proposes that collection description has potential in European information landscape in developing user services and in supporting the development of the European Digital Library - Europeana.

## 1. INTRODUCTION

The collections landscape in Europe is a complex one. Holdings on particular topics or themes are widely distributed between institutions. Digitization programmes across Europe are at different stages. It is often difficult to know if a particular collection or item (for example, an edition of a published work) has been digitized by an institution and, if it has, how to get access to it. Collection description came to the fore in this landscape initially as a result of work for the Research Support Libraries Programme (RSLP) in the UK, which wished to highlight the outcomes of its funding in a portal (Powell, 2000).

The RSLP developed a collection description schema which was later implemented by other programmes to provide a finding aid for collections. Through the work of the Dublin Core Metadata Initiative (DCMI) collection description working group, the schema has evolved into an international standard that can be related to parallel initiatives such as NISO Metasearch and in the Archives community (DCMI, 2008; Sweet & Thomas, 2000).

European countries have invested significantly in digitization programmes and the results are transforming access to cultural content - books, films, photographs, manuscripts, speeches, music, artworks and the archaeological architectural heritage – are all now available in digital form online. These contents are distributed across Europe in institutional repositories and made available to the public through institutions' websites. Recent years have seen a number of initiatives to harvest item level metadata from institutional repositories to create regional, national and now European access points. In this environment of networked repositories, Collection description has an increasing role to play:

- It offers a standard framework that can be used by libraries, museums, archives and other institutions for registries of digital content.
- Collection description registries, such as the MICHAEL European Service (MICHAEL, 2008), provide a rapid way of surveying the landscape and finding out which institutions hold collections of digital objects, their coverage and where they are accessible.
- Collection descriptions provide contextual information about objects, which are generally stored by institutions in collections of similar items under the same management framework and terms and conditions (Foulonneau, 2005; Powell, 2000; Dempsey, 1999).
- Registries of collections and services offer help to users (both human and machine) in discovering the existence of collections and in finding information about the terms and conditions for use, what to expect and how to access it (Pearce, 2000).

This paper looks at the evolution of a Europe-wide project to catalogue digital contents at collection level into the MICHAEL European Service (<http://www.michael-culture.org/>) from the initial work on metadata schemas in MINERVA to its implementation in practice and its uses in the European Digital Library - Europeana.

## 2. MINERVA: INVENTORIES AND DISCOVERY OF DIGITIZED CONTENT

MINERVA (the Ministerial Network for Valorising Activities in Digitisation) is a thematic network in the area of cultural, scientific and scholarly content supported by three projects funded through the European Commission's IST and



eContentPlus programmes: MINERVA (2003-5), MINERVA Plus (2004-6) and MINERVA EC (2006-8).

MINERVA advocated the establishment of national inventories of digital content to facilitate planning and as an aid to resource discovery. It aimed to use inventories to identify the institutions involved in digitisation, the work was in progress and the collections, services and products being produced (MINERVA, 2003a). MINERVA established a specification for inventories of digitised content, which included a data model that extended the RSLP metadata schema to focus on the process of digital cultural content creation (see figure 1).

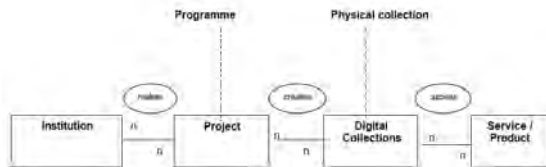


Figure 1: MINERVA Model of Digital Cultural Content Creation

The MINERVA model identified four core entities:

- Institutions, the creators of digital resources that receive the money for a project and develop competencies in the field.
- Projects, set up to carry out digitisation activities with defined start and end dates.
- Digital collections, or descriptions written to provide an overview of the content.
- Service/products, systems which allow end-users to access the digital content.

The project went on to carry out a feasibility study into establishing a platform to publish a directory of digitisation activities, which was informed by work by the Ministry of Culture and Communication in France to a software platform for its inventory in 2000 (MINERVA, 2003b).

### 3. MICHAEL AND MICHAEL PLUS

MICHAEL (Multilingual Inventory of Cultural Heritage in Europe) is a deployment initiative supported by two projects co-financed by the eTEN programme: MICHAEL (2004-8) and MICHAEL Plus (2006-8). If the MINERVA project's focus was on establishing models and specifications, MICHAEL's has been on implementation and survey.

#### 3.1 MICHAEL Data Model and Software

MICHAEL implemented the MINERVA model and the French Inventory platform, with some modifications, and went on to roll out the survey of digital collections across Europe. Beginning with just three countries (France, Italy and the UK), the extended, through MICHAEL Plus, to include twenty countries (Belgium, Bulgaria, Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Israel, Italy, Latvia, Malta, the Netherlands, Poland, Spain, Slovakia, Sweden, the United Kingdom). Each country has established a Collection Description Service, based on their implementation of the MICHAEL software platform, and begun cataloguing the digital collections and service/products in their country.

Several thousand collections and services representing several million digital objects have now been catalogued (Caffo and De Francesco, 2007).

The MICHAEL data model focuses on digital collections and access to them, also covering related information on institutions, projects or programmes and physical collections (MICHAEL, 2005). It has five core entities which allow different kinds of record to be created and linked allowing information to be reused, for example the contact details for an institution (see figure 2). For each entity, the data model defines mandatory, recommended and optional fields to meet the requirements for resource discovery (e.g., identifier, title, description, legal status, subject and period are all mandatory fields in the digital collections entity). Mandatory relationships between entities are also defined to meet user needs, for example a digital collection record must be related to at least one institution record and one service record to provide users with the information they need to find and use the collection.

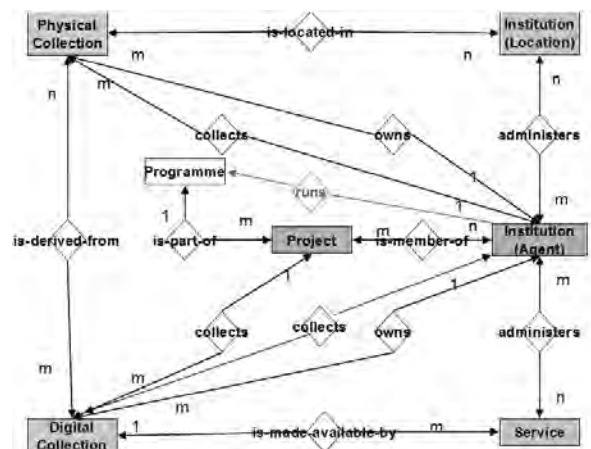


Figure 2: MICHAEL Data Model

Within the MICHAEL software platform each of the five entities is implemented as a type of record with its own data entry forms and embedded terminology lists. Meta-metadata is automatically captured by the system when records are created – this provides information about the creation, modification and updating of the record and its source database. The meta-metadata is important in the sharing and re-use of MICHAEL records from national inventories in the MICHAEL European Service and other applications.

The data model and the MICHAEL software platform have both been important in enabling the initiative to be extended to so many new countries.

The MICHAEL software platform comprises of open source software component, which are all freely available for distribution. The software base consists of an XML database management system (eXist), a web application (Xdepo) and a search engine (SDX: System Documentaire XML) which is based on Apache Lucene and runs on Apache Tomcat and Cocoon (MICHAEL, 2006; Christaki et al, 2007; eXist, 2008; SDX, 2008). Documentation is available from the project to support developers in the installation and localization of the software platform.

The various components when installed provide a cataloguing system (the production module) and a publishing system (the publication module). The platform is supplied in English, the

process of localizing the platform for the new partner countries in the MICHAEL Plus project has involved translating the user interfaces, system messages and terminology lists into the national language(s) relevant for each country. Versions of the platform interfaces in various European languages are now available through the MICHAEL open source community's code base.

The MICHAEL cataloguing system incorporates web-based data entry forms which allows for remote data entry by cataloguers based in cultural institutions. Records are held as drafts in the cataloguing system until they have been checked and validated by the cultural institutions. Once validated records are published to the national MICHAEL website where they become publicly available (see MiBAC 2006/2008 and MLA 2005/2008).

The software installation package includes a publishing system with a series of templates to build the national web-site, the search engine and the capabilities to establish OAI-PMH repositories (Open Archives Initiative Protocol for Metadata Harvesting). Thus the national instances are connected to the MICHAEL European Service (see Figure 3).

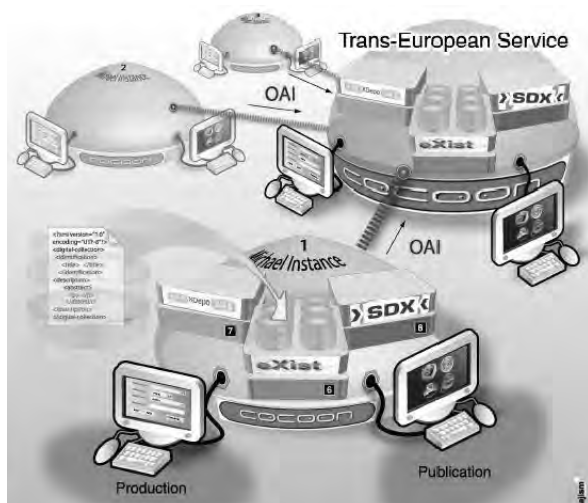


Figure 3: Interoperability in the MICHAEL Network  
© AJLSM Image Copyright 2005.

### 3.2 OAI Harvesting

In a MICHAEL instance, there are separate OAI-PMH repositories for each of the entities in the MICHAEL data model: digital collections; service/products; projects; institutions and physical collections. Each repository supports data export in three formats:

- OAI\_dc = Dublin Core metadata
- OAI\_michael = MICHAEL data model (terms are coded)
- OAI-complete = Full MICHAEL records with all terms de-coded and links to related entities exploited to include relevant information.

For example, the MICHAEL digital collection complete format covers all elements in the following groups: identification, description, subject-indexing, illustration-group, relations and metadata. All coded terms are extended to include the multilingual term labels:

```
<subject-group>
- <subject code="S003"
  scheme="michael:/uk/subjects">
  <en>Art & Culture</en>
  <cy>Celfyddyd a Diwylliant</cy>
</subject>
```

In this example from the UK national instance term labels are provided in both the Welsh and English languages. The two-letter ISO language code is used to identify the language of the term in the user interface. Additional languages may be supported by adding the appropriate labels to the terminology list (in the European service labels are available in all of the partner languages). All of the language variants of the term labels are included in the MICHAEL OAI-complete harvest format.

The MICHAEL complete format also extends relations beyond the unique identifier (which is recorded in the record itself) to include data from the targeted entity. In this example the Service ID is extended to include data from the service record:

```
<relation role="isMadeAvailableBy"
  scheme="michael:/uk/rerelations/digital-collection"
  target="UK-SE-85843094">
  <relation-infos type="service">
  <service id="UK-SE-85843094">
  <identification>
  <title>Collect Britain website
  </title>
  </identification>
```

The OAI-MICHAEL format is the standard harvesting format from MICHAEL national instances by the MICHAEL European service. The OAI-complete format is offered for harvesting of MICHAEL instances by other information services which require terminology to be provided in a de-coded format.

### 3.3 Multilingualism

The multilingual terminology lists have been important in establishing multilingual user services in the MICHAEL European portal (MICHAEL, 2006 and figure 4).



Figure 4: <http://www.michael-culture.org/>  
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MINERVA had defined a basic set of terminology resources in English but these proved insufficient for implementation in the live environment largely because richer resources were needed to support the cataloguing programmes (MINERVA, 2003a).

An early task for the MICHAEL project was to identify appropriate terminology resources. In some cases the basic lists

established by MINERVA were extended with additional terms needed in MICHAEL. In other cases international terminology resources were identified for use by the project, multilingual resources were preferred where these were available. From this base, a set of European terminology lists was then established for use in the MICHAEL platform (period, subject, spatial coverage, language, access type, digital type, digital format, physical type, audience, WAI and institution type). These lists have subsequently been translated into all of the languages of the partner countries (none of the international lists were available in all of the languages).

The availability of these multilingual terminology lists supports the integration of descriptions from the different countries into the MICHAEL European Service and the multilingual browsing offered to its users. Each country catalogues its digital cultural content into its MICHAEL national instance and the descriptions are then harvested in the OAI-MICHAEL format, with all terms coded. Multilingual term labels are then supplied by the lists incorporated into the MICHAEL European Service.

Two approaches have been adopted by MICHAEL national instances to support this level of integration. National instances have either implemented the MICHAEL-EU terminology lists using the standard codes and translating the term labels or they have implemented national lists and provided a cross-walk (or mapping) between the codes used in the national instance and the code in the MICHAEL-EU term list. The first approach simplifies the integration of data into the European Service while the second allows greater flexibility for the national instance by allowing index terms to be added to cataloguing systems at national level. Multilingual data entry forms enable cataloguers to enter free-text (such as title or description) in each of the languages supported by the national instance.

The multilingual term labels are used to support switching between languages in the user interface at both national and European level. The MICHAEL European Service is made available in all the languages of the partner countries (see figure 5 for the Greek language interface).

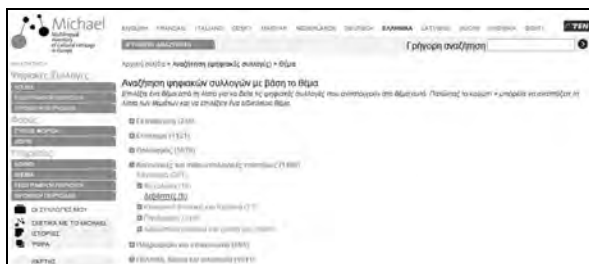


Figure 5: Greek Language Interface  
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As a result, the thousands of collection descriptions created through the national instances can be browsed by end-users of the multilingual MICHAEL service in the language of their choice. The aim has been to provide a simple and easy-to-use service that allows end-users to find and explore digital collections from institutions across Europe. MICHAEL users are able to browse through the inventory of digital resources using predefined searches, for example browse by subject:

- Education (236)
- Science (1121)
- Culture (5079)

- Social and human sciences (1406)
  - Ethnology (201)
  - Psychology (16)
  - Social policy and welfare (71)

In the French version of the user interface this becomes:

- Education (236) Science (1121) Culture (5079)
- Sciences sociales et humaines (1406) Ethnologie (201)
  - Psychologie (16) Politique et bien-être social (71)

Users work in their own language, simply clicking through the browse screens to generate a list of collection descriptions that are relevant to their interests. The collection descriptions are then displayed with all terms in the language of the interface. Free text fields are displayed in the original cataloguing language – the multilingual data entry forms mean that alternate language versions of free text are often available. The text will automatically be displayed in the language selected by the user of the user interface where it is available. Links to automatic translation tools are included in the MICHAEL European portal to offer users further options for translating text.

#### 4. USERS AND INFORMATION RESOURCES

According to Heaney (2005) using resources “consists, at the simplest level, of bringing a User and a Resource together. In some cases the User and the Resource are brought together via an Intermediary acting as an ‘honest broker’ between the two”. MICHAEL has sought to play this role.

##### 4.1 Human Users

The resources that are promoted to users through its services come from trusted sources (libraries, museums and archives) and the descriptions of those resources are quality assured. Positive steps are taken through the service description in MICHAEL to provide users with the information that they need to answer some basic questions:

- Is the service suitable for my needs, or those of my students?
- Will I be able to use the service or do I need specific equipment?
- Are there any access restrictions?
- Where is the content?

The question ‘is the service suitable for my needs or those of my students’ is answered in part by the audience element of the service description – which describes whether a resource is designed for use in formal education. The service description also provides information about whether the resource is online or offline, if it is freely available or on restricted access and if any special equipment is required to view the resource (such as a plug-in for VRML (Virtual Reality Modeling Language).

The final question ‘where is the content’ is perhaps the most important for most users. MICHAEL service records provide a hyperlink to online resources, which means that users are able to go quickly from MICHAEL to the online resource, access it and use those services that are particularly relevant to their interests, ages or learning stages. In this way MICHAEL acts as an intermediary between a user and the resources in which they are interested (see figure 6).

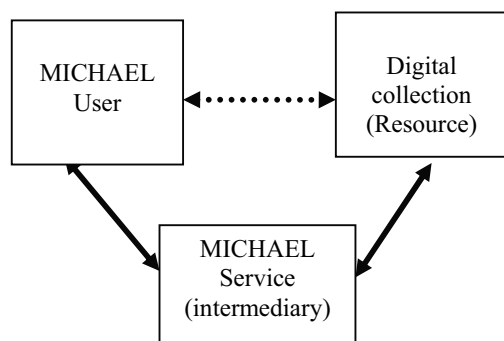


Figure 6: Transaction Overview Based on Heaney 2005

MICHAEL provides a human readable interface that enables its users to go on to access and then explore the resources that it describes. It does not support automated transactions between user and the resource. But the concept of having an intermediary acting as an “honest broker” is particularly important for some types of users. For example, for teachers who are looking for online resources for use by young students in the classroom MICHAEL offers a way of finding content from trusted sources – archives, libraries, museums and other cultural institutions. As many schools block the use of general search engines within classrooms, MICHAEL offers teachers a trusted search service that may be used by children in class.

#### 4.2 Machine-to-Machine Services

We have focused on the human use of collection and service descriptions through the MICHAEL user interface but they also have potential in machine-to-machine environments. Heaney (2005) discusses the likelihood of restrictions to the online use of collection descriptions. In MICHAEL national instances collection descriptions are licensed for use under the Creative Commons non-commercial share-alike License (Creative Commons, undated), which allows them to be incorporated into the MICHAEL European Service – and other information services.



Figure 7: MICHAEL Powering a Regional Information Service for North East England. © 2008 Well I Never

For example, figure 7 illustrates the way in which data from the UK national instance has been used to create an information service for North East England (MLA North East, 2008). “Well I Never!” aims to provide a resource for teachers, pupils, parents and carers to find out about learning resources and cultural venues in the North East region. The collections element of the service is provided by using the web-services offered to web-developers by the MICHAEL UK (MLA, 2008).

Data from the UK national instance has also been harvested via OAI-PMH for integration into learning management systems used by teachers in school (see figure 8).



Figure 8: MICHAEL Data in a Learning Platform

Interoperability and integration of data from MICHAEL into other information services has been supported by mappings to other information standards, such as the Dublin Core. A Dublin Core Application Profile has been prepared for MICHAEL and mappings have also been prepared for the RSLP schema, the JISC’s Information Environment Service Registry (IESR) and IEEE Learning Object Metadata (LOM) (Johnson, 2005a, 2005b and 2006; Fernie 2008). In this way, MICHAEL collection descriptions can be made available to other user services.

## 5. COLLECTIONS AND ITEMS

There are a number of initiatives at national level in Europe which are creating portals that integrate collection descriptions with item level metadata to provide joined-up search services. These initiatives include the CulturaItalia portal from Italy which incorporates collection descriptions from MICHAEL-IT alongside item-level descriptions from Italian institutions (see Figure 9) (MiBAC, 2008).



Figure 9: CulturaItalia  
© 2006-2008 Ministero per i Beni e le Attività Culturali

The Culture.Fr collections portal from France, Germany’s BAM Portal and the People’s Network Discover Service from the UK also include collection descriptions from MICHAEL national instances (MCC, 2008; BAM, 2008; MLA, 2005/6). These portals offer potential for simplifying search processes for users, simplifying the journey from an interesting collection

to digital objects or from one interesting object to related items from the same collection.

The People's Network Discover Service was developed by the Museums, Libraries and Archives Council (MLA) to demonstrate the potential to provide users with seamless access to cultural information from a distributed network of public libraries, museums, archives and other cultural institutions (MLA, 2005/6, Fernie, 2007). Discover includes both item level metadata harvested directly from cultural institutions and collection descriptions harvested from MICHAEL-UK and MLA's Cornucopia database. Cultural institutions that make their content available via Discover are asked to create a description for their digital collection in MICHAEL-UK and to map their item-level metadata to the Discover Service's Dublin-Core Application Profile (Powell, 2005).

The relation between an item and the collection that the item is part of is provided by `dcterms:isPartOf`. As both the institution's item-level metadata and MICHAEL-UK are targeted by the Discover Service (both OAI-PMH and web-services are used) there is the potential to bring together item level information with the collection description and to offer users contextual information about the collections from which an item came.

There are other examples of information services that make use of collection descriptions alongside item-level metadata. Foulonneau (2005) has written about experimentation by the University of Illinois in using collection descriptions with item-level metadata to improve search and discovery across the resources held by a group of academic research libraries. In Europe, The European Library (TEL) also uses collection descriptions as a simple way of enabling users to filter searches. In the TEL portal users may use collection descriptions to limit their searches to target, for example, item records from the collections of a particular National Library or for a particular type of content (such as children's literature) (TEL, 2005-8).

## 6. COLLECTIONS IN THE CONTEXT OF THE EUROPEAN DIGITAL LIBRARY

Work is now underway to build the European Digital Library. The first projects are underway to establish the frameworks and processes that will enable cultural institutions to make their digital contents available to the Library. It seems likely that this will be through a network of repositories (regional, national and domain specific, subject specialist). In this landscape collection description has a role to play.

There are two areas in which collection/service description can be useful in helping to build the contents of the European Digital Library. The first is in helping to identify those cultural institutions that are ready to meet the technical requirements specified for Europeana (the name chosen for the European Digital Library portal). These requirements include the existence of item level metadata and an OAI-PMH repository available for harvesting. The second is in exploiting the potential of the registry of European collections and services to identify cultural institutions with content that is relevant to the themes currently being developed – the initial call for content for Europeana identified these themes for which content was sought, these were: cities, crime and punishment, travel & tourism, music and social life (EDLNet, 2008b).

Collection descriptions also have potential within the European Digital Library system. They can be used to augment item-level metadata with contextual information about a particular object, providing for example details about the institution which manages the object with general information about its collections. There could be potential value in using collection descriptions to reveal items that are related to a discovered object; other objects from the same collection that may also be of interest to a user of the service. This might offer users an element of serendipity or chance discovery in their searches that could excite interest.

Collection descriptions could offer a potential way of allowing users of the European Digital Library to explore the collections landscape and find out more about the holdings of institutions in a particular area. At the time of writing the EDLNet project was planning to harvest collection descriptions from MICHAEL-EU and other sources for the Europeana portal (EDLNet, 2008a).

## 7. SUSTAINABILITY

The MICHAEL and MICHAEL Plus projects have established an International not-for-profit association, the MICHAEL Culture AISBL, to continue the MICHAEL European Service, platform and to enable cooperation in the development of the European Digital Library (MICHAEL, 2008). National instances established during the eTEN projects have become members of the Association; membership is of course open to new instances and to interested parties.

At national level, MICHAEL platforms have become embedded into national programmes. For example, in France digital collections created as a result of funding through the national digitization plan are catalogued in the French national MICHAEL instance. Each country has developed its own strategy for continuing cataloguing programmes and liaising with its cultural institutions. The result is that new digital collections are regularly being registered in MICHAEL national instances and published through the MICHAEL European Service.

## 8. CONCLUSIONS

In this paper we have aimed to provide an overview of a series of developments that have taken place in Europe over the last five years. The results have built up over time. The initial work by the MINERVA project on data models and specifications later enabled the implementation of a Collection Description platform in the MICHAEL project. The success of this platform, which can be attested to by the rapidity of its adoption in countries across Europe, is in part due to the adoption of common standards and open source software and in part to the demand for collection description in the European information environment. National authorities, regional administrations and funding bodies recognize the value of describing digital outputs at collection level in order to plan future digitization programmes and to develop user services. The MICHAEL project demonstrates the potential for developing discovery services based on collection descriptions for human users. The demand for MICHAEL collection descriptions by external information services also demonstrates their potential for reuse in services that are targeted towards tourism, education or other audiences. In the new generation of national and European digital library services, collection and

service descriptions provide context and have perhaps yet untapped potential to refine item-level searching.

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## NESTOR – THE GERMAN NETWORK OF EXPERTISE IN DIGITAL LONG-TERM PRESERVATION

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**KEY WORDS:** Digital Preservation, Cooperation, Long-term availability, Collaboration, Network of Expertise, Digital Objects

### ABSTRACT:

The German network of expertise in digital long-term preservation, nestor, brings together different kinds of institutions to establish a competence center for raising awareness about digital preservation issues and developing solution approaches. The network facilitates the exchange of information about present activities concerning digital preservation of our cultural heritage. Therefore, nestor brings together experts from different parties concerned with long-term preservation to focus and exchange domain-specific know-how. A wide variety of people from different institutions are involved in nestor to help establish a cross-sectoral community for long-term preservation activities. nestor also collaborates with international partners and projects to trigger synergies.

### 1. INTRODUCTION

nestor is a network of expertise for long-term preservation of digital resources in Germany.

The volume of digital objects is increasing as well as the importance of digital information for economy, science and society. But as yet, there is no global strategy for long-term preservation and accessibility. Our cultural heritage is at risk. nestor aims to increase the awareness of digital preservation problems and coordinate different solution approaches.

The current project started in September 2006 as a successor to the first stage nestor project that ran from 2003 to 2006. This second stage will continue until summer 2009 and is funded by the German Federal Ministry of Education and Research. During this stage, a sustainable form of organisation has to be developed in order to maintain the network after the funding period.

nestor brings together activities and expertise from different kinds of institutions involved in long-term preservation such as libraries, museums, archives, universities, research institutions etc. These institutions are all concerned with digital preservation: not only do e-books and e-journals, online dissertations and other online publications have to be stored, moreover they must remain accessible to their users. Archives are presented with electronic files which need to be transferred into digital records and stored. Museums accept digital artefacts in their collections and, in line with their function as information mediators, play an important role in creating and preserving digital objects. Within science and research, not only scientific results, but also the primary or raw data are being digitally published and have to be stored for reuse and as evidence.

Aside from the increase of native digital documents, the digitalization of printed publications is also in process. Formats, data media, as well as soft- and hardware are rapidly developing which complicates the long-term accessibility of digital objects.

The paper describes the history of the nestor project itself and its goals. It also gives an overview on the different activities nestor is involved in. It also focuses on a model successor organization to nestor, which will take over custody of all aspects and activities concerning long-term preservation once the project is ended.

### 2. NESTOR AS A NETWORK OF EXPERTISE

#### 2.1 History

The topic of digital preservation came up in 1995 at the German Research Foundation and was initially seen as a task for digital libraries. Then it was discovered to be a complex topic involving a wide range of issues that have to be solved in cooperation with all stakeholders: Not only libraries and information centres but many other institutions.

After some basic workshops and meetings, nestor I was established as sub-project of the network of expertise of “New services, standardization and metadata”, funded by the Federal Ministry of Education and Research. The first stage of this project ran from 2003 until 2006 with six partners.

During the currently proceeding second stage (from 2006 until 2009) seven partners are continuing the task. The partners are:

- the German National Library,
- the State and University Library Göttingen,
- the Bavarian State Library Munich,
- the Computer and Media Service of Humboldt University Berlin,
- the Institute for Museum Research Berlin,
- the Federal State Archives Koblenz and
- the University Hagen (FernUniversität).

The nestor project focuses the available long-term preservation know-how, energies and skills – forming the basis for a future alliance dedicated to the preservation of Germany's digital heritage.

#### 2.2 Goals of nestor

The main goal of nestor is to secure long-term preservation and long-term accessibility of digital resources. Therefore the partners created a network that provides the exchange of information about present activities concerning digital preservation. In addition to the project partners, many other people from different institutions are engaged in nestor. As a result, a broad range of people from different institutions are involved in nestor, forming a cross-sectoral community around long-term preservation activities. nestor also collaborates with international partners and projects to trigger synergies.



To ensure appropriate measures and activities, it is necessary to increase awareness about the problems of digital preservation. Digital preservation is a matter of concern both for experts in cultural heritage institutions as well as for the general public. nestor aims to create an information and communication platform to bring together existing activities and to propose further measures. nestor intends to set up a durable cooperative infrastructure which bundles a wide variety of complementary skills which can be developed and exploited.

Finally, the project partners are developing a model for a permanent organization to coordinate and represent all aspects and activities concerning long-term storage beyond the duration of the project.

### 2.3 Tasks of nestor

nestor's goal is to make distributed expertise visible and accessible. In order to distribute all kind of information concerning digital preservation, the nestor website serves as information platform. nestor wants to present and bring into discussion organizational and technical models of procedure which are suitable and enduring for the long-term preservation of digital resources.

The subject gateway provides access to projects and publications on specific aspects of long-term storage and accessibility. It is connected to the Preservation Access to Digital Information (PADI) database located at the National Library of Australia.

Regarding the complex questions that archives, libraries and museums are faced with, cooperative solutions have to be found. Therefore nestor supports institutions to initiate cooperation. The database "Who – Where – What" contains the personal profiles of a number of experts with special interests and expertise. It supports people in finding specialists to solve concrete problems as well as partners for collaborative work.

A periodically published newsletter provides information on activities, new projects, events etc. In addition to this service, a calendar lists all important events that are concerned with different aspects of digital long-term archiving and accessibility in Germany and in a European as well as in a global context. To serve the diverse requirements, a variety of different materials are published and provided via the nestor website.

nestor is also engaged in the field of certification and standardisation. It wants to further the development of standards through participation in national and international standardisation forums and committees. It provides catalogues of criteria for trusted repositories as well as for persistent identifiers. On the initiative of nestor, the DIN (the German Standardisation Body) has recently established a subcommittee for the needs of long-term preservation. It resides within the Information and Documentation Standards Committee.

Currently, nestor focuses on two main topics in relation to standardisation: the first is audit and certification of digital repositories and the second is the standardisation of the ingest process, i.e. the automated delivery of electronic objects to the archive.

To build awareness and provide information about long-term preservation, nestor has started several PR initiatives and maintains the project's website with different services and publications. The project partners also join national and

international conferences in order to make the project known, to learn from foreign approaches and to keep up to date with the international developments.

### 2.4 Activities of nestor

nestor is engaged in a wide range of activities to promote the topic and to serve as a competent contact point regarding all aspects of digital long-term preservation. The challenges of archiving different materials require a variety of activities. These challenges include contradictory requirements with regard to duration of storage, technical issues, legal aspect etc. Even for experts, it is difficult to overlook all the aspects related to digital preservation. The nestor management structure gives consideration to this multitude of fields of activity by separating between structural and thematic tasks. Structural issues are tackled in working packages and thematic tasks are tackled in working groups. The membership is not limited to project partners but is open to experts from all parties concerned with the specific aspects of the working packages, respectively working groups.

A typical structural task is PR. To provide all information about long-term preservation and nestor, considerable public relation work is necessary. Project Management constitutes one working package as well as the development of a sustainable organisation model is another working package of its own.

As another structural problem, nestor has identified an extensive need for training and education in digital long term preservation. One nestor working package is dedicated to the development of effective qualification programs and training materials. Several training events have started with the nestor Spring School 2007 and are continued with workshops and seminars. This ongoing series of events is intended to serve the needs of different communities.

An important key activity is the development of e-learning modules on digital preservation in collaboration with university partners. The nestor efforts in comprehensive education and training are presented in the "nestor Handbook – An Encyclopaedia in digital Preservation" which is intended as a living document. The most recent version is available on the nestor website. Anyhow, in practice it shows that besides the tasks just listed, structural and thematic tasks keep overlapping each other. One working package is committed to the advancement of standardisation. It is aiming at integrating national standardisation activities in international contexts and advancing standardisation and the use of standards on a rather high level. Two working groups deal with standardisation at a more practical level; the working group "Standardisation" and "Trusted Repositories/Certification".

One of the goals of the working group "Standardisation" is to achieve interoperability and trustworthiness of Persistent Identifiers. Guidelines for the ingest process will be published at the end of the year. Members of the working group are engaged in national and international standardisation bodies.

The working group "Trusted Repositories/Certification" was launched in December 2004. It works on identifying relevant features and ranges to evaluate existing and emerging digital object repositories in order to form a web of trustworthiness. Those digital repositories can then function as long-term digital archives within various environments, the library community, the classical archives world, the museums community and also

other data producers like governmental institutions, world data centers, publishing houses, etc. The nestor working group consists of representatives from libraries, archives, museums, data centers, national libraries (Germany, Austria), publishers and certification experts. The working group has developed a catalogue of criteria for trusted digital repositories. Version 1 is published and available on the website. A new version will be published soon.

Other structural challenges are the integration of further communities. The goal of one working package is to promote activities within the archive and museum communities. Therefore special events and workshops are held. In practice, the integration of further communities works e.g. really good in the working group “Media”, which is aspiring to become a centre of knowledge and expertise on best-practice approaches to the problem of long-term accessibility of digital, non-text based media. With the participation of renowned experts on the topic, a virtual meeting point has been established and a handbook on long-term archiving of non-text based media will be published with special consideration of problems regarding file formats, hardware for the creation of archival backup copies and workflow.

Synergies between eScience, grid computing and long-term preservation are even in the focus of a working package and two working groups. eScience stands for collaborative and at the same time distributed research made possible by most modern infrastructure. eScience based on Grid technology with tremendous data amounts and the technical dynamic generates a special need for long-term preservation. Conversely, this technology could have a tremendous potential for the implementation of long-term archive systems. When the project was planned it was intended to have four surveys conducted in a working package that should outline this new area with its opportunities and risks. The task of the working group “eScience and long-term preservation” was to extract a roadmap from the survey results with regard to integration of Grid-technology and digital long-term preservation. The working group “Scientific Raw Data” dealt with the question how to preserve large amounts of scientific data. In practice, the tasks of the three organizational units were so closely connected that the separation didn’t make a lot of sense and the working package and the working groups merged.

The working group “Cooperative long-term preservation” promotes a co-operative approach and strengthens binding legal deposit directives. Furthermore, different types of co-operations have been evaluated and the results will be published in 2008. Technical and legal aspects as well as workflow issues relating to cooperative long-term preservation are the main topics of the working group. During the runtime of the project an additional subgroup was created, which works on recommendations concerning copyright act regarding long-term archiving.

In conclusion it can be said that in spite of careful planning, it took some time until the nestor network translated the project plan in living structures. On the other hand, a network must be flexible enough to react on new demands recognized while dealing with related questions. Despite the difficulties that are connected with the organization of large cooperative projects, nestor could be regarded as a successful example for the attempt to deal with the multifaceted challenges of digital preservation

### 3. SUSTAINABLE ORGANIZATION

Digital long-term preservation is an ongoing task and should undertaken as part of a partnership, with distributed task are A goal of nestor is the constitution of a permanent form organization for all issues of long-term preservation as well the development of national and international agreements and the assignment of tasks. During the two stages of the project nestor has established a cooperative cross-sectoral infrastructure in the range of digital preservation. It is well-known as well Germany as well as internationally as a competent network which provides a framework for the challenge of digital long term archiving and accessibility. Preservation of the digital heritage requires additional and sustained effort on the part the policy makers, authors, publishers, hard and software manufacturers, and the cultural and scientific memory organisations. Digital preservation is no end in itself but preserves exactly the value that lies in the data that is stored and held accessible so that it is worth the additional effort.

A sustainable coordination structure in which the actual institutions can interact must be launched. The durable coordination structure to be set up should support and link institutions tasked with long-term digital preservation, promote the information, organise participation in the international discussion, propose and supervise research projects, implement initial and further long-term digital preservation training Germany and assume other coordination tasks in the field long-term digital preservation.

After the funding is terminated, almost all current nestor partners will transitionally continue some of the tasks they working on. Based on a cooperation agreement, responsibilities will be defined for every institution. Similar the current network of a variety of people engaged in the nestor working groups, the future agreement will be open to interested institutions.

As the preservation of digital objects is a task of national importance, in the long run, the goal has to be a permanent and durable organization. It has to be located at a federal, state and local level and appropriate financial resources must be made available accordingly. Financing digital long-term preservation is an ongoing task, an investment for the future which should binding upon all those involved.

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## DIGITIZATION, DOCUMENTATION AND DISSEMINATION OF DIMITRIOS KASLAS' ARCHIVE

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**KEY WORDS:** digitization, documentation, dissemination, archives.

### ABSTRACT:

Nowadays several historical and cultural archives are threatened by extinction leaving historical and cultural heritage records of immense importance unexploited. To address this issue there is an increasing demand for digitization, documentation and dissemination of such material following rigorous methodologies. This paper evaluates universal digitization and documentation methodologies and presents practical issues that arise during the application of these methods to digitise and document Dimitrios Kaslas' archive, as well as data processing issues for the dissemination of this material over the Internet. Dimitrios Kaslas' archive consists of unpublished material of the historical periods of the Asia Minor until the II World War such as, political and military photographs, postcards, maps, political and military documents and textbooks and personal belongings. The presented project is the outcome of an MSc thesis at the Hellenic Open University, in the Faculty of Applied Arts, Graphic Arts – Multimedia.

### 1. INTRODUCTION

Currently several historical and cultural archives are being destroyed and various historical and cultural heritage records of immense importance are in danger to be left unexploited. Organisations like the European Parliament and the Council have recognised the demand for digitization, documentation and dissemination of collections and archives and devoted grand funding towards generating electronic content, as well as developing technologies to make digital content in Europe more accessible, usable and exploitable (see eContent<sup>plus</sup> programme specifications). The potential benefits of information in digital form—unfettered access, flexibility, enhanced capabilities for analysis and manipulation—are profound, particularly to those concerned with education and research. To use digitization as a tool to provide worthwhile, enduring access to treasured cultural and historical resources, one must become informed, establish guidelines, and proceed in rational, measured steps to assure that such reformatting of visual matter is accomplished as well and as cost-effectively as possible.

This paper evaluates universal digitization and documentation methodologies and highlights practical issues that arise during the application of these methods to digitise and document Dimitrios Kaslas' archive. This archive is of particular importance for two reasons, its value to the Greek history during the II World War and the richness of the type of material to be digitized.

The paper includes the following structure: section two presents Dimitrios Kaslas's Archive; section three describes the candidate digitization methodologies and explains why Dublin Core has been used; sections four, five and six present the digitization of Kaslas's Archive of documents and manuscripts, 3D Objects Digitization, and audio and video capture accordingly; section seven deals with the documentation of the

archive; while section eight deals with dissemination of the archive; the paper closes with conclusions in section nine.

### 2. DIMITRIOS KASLAS'S ARCHIVE

Dimitrios Kaslas' archive contains unpublished material of the historical periods of the Asia Minor until the II World War. A substantial part of the archive refers to the action of the II battalion of the 5th Infantry Regiment from Trikala which defended the ridge 731, where the Greek-Italian war was actually decided. There are also references to the early years of D. G. Kaslas' life during the National Resistance period as well as, to his persecutions and to the latest years of his life.

The type of material that consist the archive to be digitized are: mainly political and military photographs; postcards; maps; decisions; war orders; manuscripts; political and military documents; protocols; identities; military textbooks; personal belongings. One of the aims of the digitization and documentation process of the particular collection was to capture Dimitrios Kaslas's personal experience about his collection by recording himself providing information about various items of the archive. This would require audio and/or video capture. Thus, there was a requirement of following a methodology for digitizing and documenting in a standardised format different type of material which consisted the archive.

The following section presents the candidate methodologies for the digitization and documentation of the archive.

### 3. DIGITIZATION METHODOLOGIES

The candidate methodologies for the digitization of the "Dimitrios Kaslas' archives" were the following:

- the "Minerva Network guide of good practices" (Dawson *et al.*, 2004)

- the guide of good practices for the digitization and long term preservation of cultural content of the High Performance Information Systems Laboratory (HPCLab), the University of Patras (Galani *et al.*, 2005)
- the Concise Guide for the digitization of video and sound of the Laboratory for Digitized Process of Image, Video and Multimedia Systems, of the National Technical University of Athens (Moshos, Hatzistamou & Aravani, 2006)
- the "DIGITECH III: Study of 3-dimensional digitization technologies" study by the Cultural and Educational Technology Institute (C.E.T.I.) for the digitization of three dimensional (3D) artefacts (Arnaoutoglou *et al.*, 2005).

Particularly the Minerva Network guide of good practices and the HPCLab guide of good practices for the digitization and long term preservation of cultural content, were the main guides for the current project (Drake, Justrell & Tamaro, 2003). The selection criteria for the methodology to be used where mainly the fact that the MINERVA Plus initiative intends to enlarge the existing thematic network of European Ministries to discuss, correlate and harmonise activities carried out in digitisation of cultural and scientific content, for creating an agreed European common platform, promoting recommendations and guidelines about digitisation, metadata, long-term accessibility and preservation. The reason that the HPCLab guide of good practices for the digitization and long term preservation of cultural content was used it was because it adopted the MINERVA Plus initiative research's results. The application of the HPCLab guide of good practices for the digitization and long term preservation of cultural content:

- reassures good quality of the digital content applying the European experience, but also the good practices from other countries, such as the USA, Canada and Australia
- increases interoperability due to the use of widely acceptable models for digital content
- decreases the probability of repeating the digitisation process of the same objects in the future through the exploitation of good practices for the transformation of prototypes in digital form and the long-term maintenance of digital content.

For the documentation and metadata recording the "Dublin Core" standard (Dublin Core Metadata Element Set, Version 1.1. Dublin Core Metadata Initiative, (n.d.)) has been adopted. The Dublin Core metadata element set is standard for cross-domain information resource description. It provides a simple and standardised set of conventions for describing things online in ways that make them easier to find. Dublin Core is widely used to describe digital materials such as video, sound, image, text, and composite media like web pages. Implementations of Dublin Core typically make use of XML and are Resource Description Framework based. Dublin Core is defined by ISO in 2003 ISO Standard 15836, and NISO Standard Z39.85-2007.

The semantics of Dublin Core were established and are maintained by an international, cross-disciplinary group of professionals from librarianship, computer science, text encoding, the museum community, and other related fields of scholarship and practice.

Due to its simplicity Dublin Core allows even non-specialised people to create descriptive registrations of content for effective retrieval in networked environment. In addition, the Dublin Core metadata common semantics ensures increased visibility and accessibility to the digital content.

The Dublin Core as a descriptive standard covers the Dimitrios Kaslas's archive documentation requirements (mainly photographs and documents) that concentrate mainly on:

- the description and the identification of data in the archive
- searching for data, and
- data retrieval.

#### 4. DOCUMENTS AND MANUSCRIPTS DIGITIZATION

With regard to issues related to artefacts' safety during the digitization process various precautions have been taken to ensure that the artefacts would not be damaged. The artefacts digitization process took place at the area that they were stored, thus any dangers that might have been caused by moving the artefacts to different places has been eliminated. The actual digitalization process has been realised very thoroughly following the appropriate preparation of artefacts such as, cleaning surfaces and strengthening fragile areas with special film.

Some work that took place prior to the digitalisation of the artefacts was their classification, numbering, placement and association. It was also checked if there was sufficient documentation for the artefacts to be digitised (description, structure, bibliographic sources etc). Fortunately most of the artefacts were well documented, due to its owner systematic effort. Parts of the archive that lacked adequate justification were completed with sufficient informative material such as, testimonies, bibliography etc.

Another parameter that was examined prior to the digitalisation of the artefacts was the digitized content requirements according to the type of use (to be published on the Internet, to be distributed on CDs, to be printed etc). It was concluded that if the material were initially saved as Tagged Image File Format (TIFF) format, with 600dpi resolution, could be then easily converted to any other type of format JPEG or PNG to be used on the Internet.

#### 5. 3D OBJECTS DIGITIZATION

As already stated in (Section 3) the 3D digitization of artefacts, (mainly personal objects of Dimitrios Kaslas's archive) was based on the "DIGITECH III: Study of 3-dimensional digitization technologies" study by the Cultural and Educational Technology Institute (C.E.T.I.) for the digitization of three dimensional Mobile and Stable objects (Arnaoutoglou *et al.*, 2005). These objects are saved up to today in very good condition due to the excellent care by the archive's owners.

The 3D digitization of Dimitrios Kaslas's archive was conducted at the premises of "Future Technology Systems Company" at Volos, Greece. Due to limited budget only two objects were digitized in 3D, a pocket watch since 1900 (see Figures 1 and 2) and a military whistle (see Figures 4 and 6).

The 3D scanner which was used for the 3D digitization consists of a jointed arm (cimcore) full of functional co-ordinates on which a laser head is placed (see Figures 3, 4 and 5 below). It is characterised by 16-micro precision and the laser head enables the recording of 23.000 points a second. The 3D Laser scanner assured complete safety as there was no direct contact with the scanned objects.

For 3D scanning, geometry generation and 3D object editing “KUBE V.13.0 Build 250” has been used. While for texture mapping “Deep UV – Deep Paint” by Right Hemisphere has been used. The files that have been generated from the 3D scanning process were saved in the following formats: VRML, OBJ and Web Publishing.

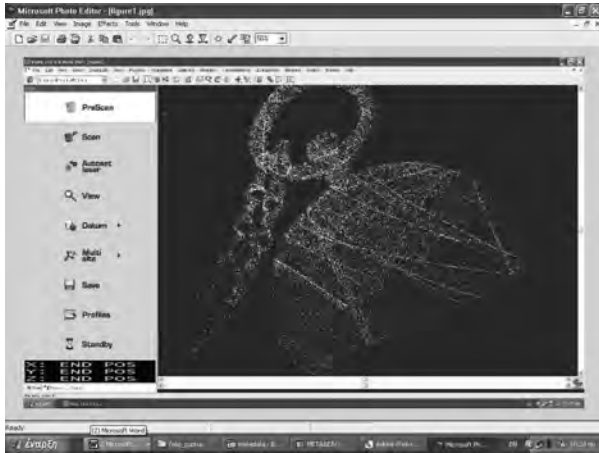


Figure 1: Cloud of points for the pocket watch

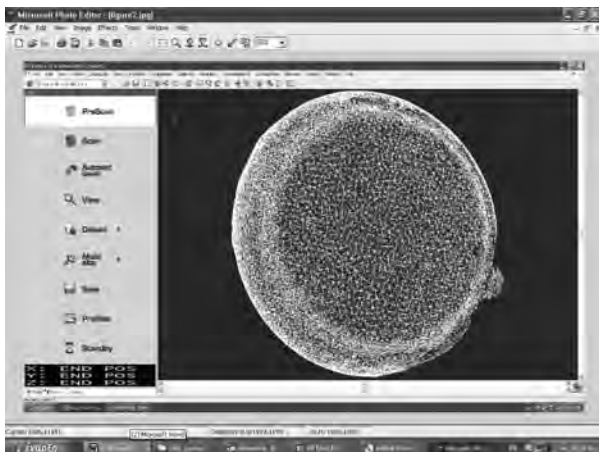


Figure 2: Polygonal grid for the pocket watch



Figure 3: Jointed arm (cimcore) and Laser head (METRIS)



Figure 4: Scanning of the military whistle



Image 5: Laser head (METRIS)

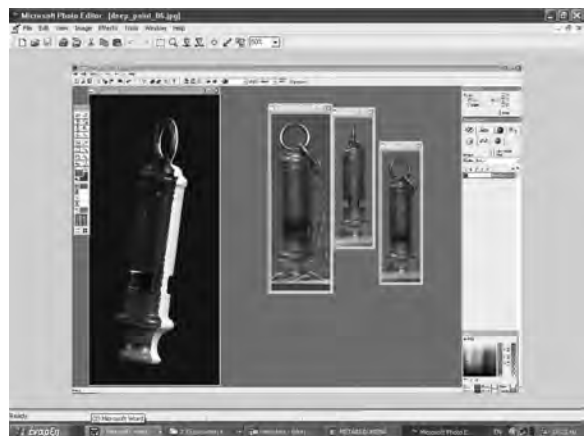


Figure 6: Military whistle texture Mapping

**6. AUDIO AND VIDEO DIGITIZATION/CAPTURE**

The audio digitization for Dimitrios Kaslas’s archive consists of several recorded pieces that denote unknown aspects of Dimitrios Kaslas’s action to the National Popular Liberation Army (ELAS) and complete a part of the archive for which there is not enough data. More precisely these recorded pieces are:

- a three minutes audio recording by Theodoro Kallino (Capten of the 13<sup>th</sup> regiment of ELAS and Dimitrios Kaslas's commander)
- a three minutes audio recording by Dimitrios Vogia (link of the 52nd regiment of ELAS from April 1943 until the domestic warfare events of December 1944, where Dimitrios Kaslas was a commander)

For the digitization and processing of the digital audio files Sonic Foundry Inc. Sound Forge 9 has been used. This software provides all the required tools for altering the sample rate (11KHz), the resolution (from 8 to 16bit), the amount of audio channels (mono/stereo), the volume, as well as correcting noise and applying effects.

The video digitization for Dimitrios Kaslas's archive consists several videos from the pilgrimage at the ridge 731:

- three minutes videos from the journey
- three minutes videos from the pilgrimage at the ridge 731
- three minutes videos from Voulianas

For the video digitization and processing Adobe Premiere 7 Pro has been used. The video files that have been created were saved in Audio Video Interleave (AVI) format. AVI files can contain both audio and video data in a file container that allows synchronous audio-with-video playback. AVI files support multiple streaming audio and video and can be reproduced by common video players like Windows Media Player.

## 7. DOCUMENTATION

As already stated in (Section 3) for the documentation and metadata recording the "Dublin Core" standard has been adopted. The following elements have been recorded:

- title
- creator
- subject
- description
- publisher
- contributor
- date
- type
- format
- identifier
- source
- language
- relation
- coverage
- rights

The Dublin Core metadata pattern has been attained in Microsoft Access database. The database allows the projection

not only of the preview image of the stored digitized artefacts, but also the 15 elements of the Dublin Core metadata pattern (see Figure 7). Further, the database allows the retrieval of the digitized material in high resolution (in TIFF format).

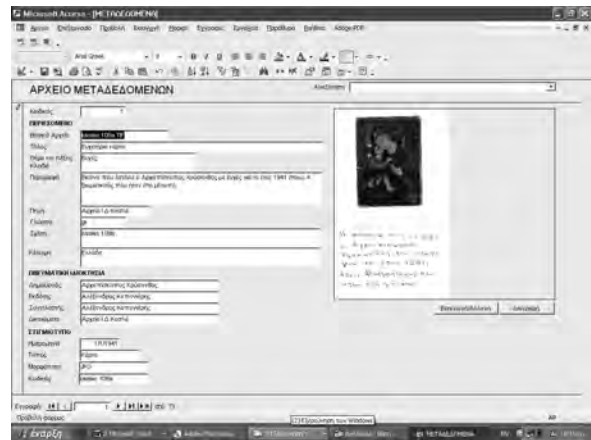


Figure 7: Metadata projection by Microsoft Access

Apart from the metadata recording in the form of an excel sheet, the metadata files were exported in XML and HTML forms for Internet usage. Below there is a sample of the XML code which has been generated for the 15 elements of the Dublin Core metadata pattern for one of the digitized artefacts of Dimitrios Kaslas's archive (see Figure 8).

```
<?xml version="1.0" ?>
<metadata xmlns="http://www.ukoln.ac.uk/metadata/dcdot/"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.ukoln.ac.uk/metadata/dcdot/
    http://www.ukoln.ac.uk/metadata/dcdot/dcdot.xsd"
  xmlns:dc="http://purl.org/dc/elements/1.1/">
  <dc:title xml:lang="en">Φωτογραφία</dc:title>
  <dc:creator>Δημήτριος Κασλάς</dc:creator>
  <dc:subject xml:lang="en">Μικρά Ασία</dc:subject>
  <dc:description xml:lang="en">Εφεσος 21 Μαρτίου 1921 -
    Δημήτριος Κασλάς</dc:description>
  <dc:publisher>Αρχείο Ι.Δ.Κασλά - Ε.Α.Π.</dc:publisher>
  <dc:contributor>Αλέξανδρος Καπανιάρης</dc:contributor>
  <dc:date>21/3/1921</dc:date>
  <dc:type>Image</dc:type>
  <dc:format>TIFF</dc:format>
  <dc:identifier>kaslas16</dc:identifier>
  <dc:source>Αρχείο Ι.Δ.Κασλά</dc:source>
  <dc:language>gr</dc:language>
  <dc:relation>kaslas 16b</dc:relation>
  <dc:coverage>Ελλάδα</dc:coverage>
  <dc:rights>Αρχείο Ι.Δ.Κασλά</dc:rights>
</metadata>
```

Figure 8: XML code for the 15 elements of the Dublin Core metadata pattern for one of the digitized artefacts of Dimitrios Kaslas's archive

## 8. ARCHIVE DISSEMINATION

The digitization and documentation of the digital content is followed by presentation and dissemination processes. Before that data needs to be converted in various formats in order to be presented in different types of media, CD, DVD, Internet, print.

As already mentioned before, the initial files that were created during the digitization process were saved in the highest possible sample rate, resolution and dimensions and thus the resulting files were large. Such high quality files could not be presented and disseminated over the Internet, first due to their size and second due to copyright protection issues. For this reason the digitized material were converted into two versions:

a lower resolution file appropriate for presentation and dissemination over the Internet and a file to be used as thumbnail to serve for previewing file content (this applies when talking about two dimensional images). Adobe Photoshop CS2 has been used for image conversion into lower resolution (72 dpi for the previewing files and 150 dpi for the content presentation over the Internet) and in different files formats (JPEG for previewing and PNG for disseminated over the Internet). Video files were simply reduced in time in order to be disseminated over the Internet.

The implementation of a web site for the presentation and dissemination of the digitized archive is the next step to be commenced. Some issues to be considered for the web site design are the following:

- the navigation to the web site to be intuitive, so that material can be easily searched and retrieved
- to be scaleable and easy to update with new content
- to support multiple languages
- to be accessible by people with special needs
- to be secure in terms of copyright protection

Furthermore, one of the future aims is the connection of the archive with the European digital library (European digital library Europeana, (n.d.)) in order to make the archive accessible to public.

## 9. CONCLUSIONS AND FUTURE TRENDS

The aim of the project described in this paper was the digitization of Dimitrios Kaslas's archive which contains valuable unpublished historic and political material of the historical periods of the Asia Minor until the II World War. Regardless its extensive size, the whole archive has been digitized providing a solid source to be used for research. The factors that contributed to this decision were the cultural importance of the archive and the imminent danger for its disappearance due to deteriorations, maintenance and state indifference for its exploitation. Finally, advantage had to be taken of the current availability of the archives owner whose impact in documenting the artefacts was irreplaceable.

The challenges that had to be addressed were:

- the vast quantity of the archive
- the wide range of material that had to be digitized (148 handwritten war orders, and 8 notepads for recording daily army activity, 240 photographs, some of which were scanned while others had to be photographed with right equipment, 20 war maps A3 size, 2 3D objects, audio and video recordings) in a relatively short period of time (as the work was an MSc project)
- the different type of equipment that was required to be brought into the area that the objects were stored (the house of the archive's owner)
- the metadata that had to be recorded

The digitized material has been saved in high resolution and various copies of each artefact have been created in different formats and resolution to serve for different purposes, for examples presentation and dissemination over the Internet. A database has been created for storing the digital data and the

related metadata, which allows searching, retrieving, previewing and downloading digital content.

Dimitrios Kaslas's archive has been used as a case study in order to evaluate the current available methodologies for digitization of cultural content that require special care, precision and systematic effort. The use of a particular digitization methodology requires special attention as it affects the cost, the time and the durability of the digitization. The methodology which has been used for the digitization of the archive was mainly the HPCLab guide of good practices for the digitization and long term preservation of cultural content (see section 3). Some of the weaknesses that have been addressed regarding this guide are as follows:

- it lacks guidelines and technical advice for setting up a photographing session, for example, issues related to the conditions of the environment in which the photographing session takes place, like lighting, distance from the artefacts according to sizes, camera settings
- it lacks guidelines for digitizing documents of large format, like maps and documents of large format that cannot be scanned and they need to be photographed
- it lacks of guidelines and technical advice for embedding different types of watermarks on digital content to assure copyright protection
- it lacks of guidelines for cataloguing the material to be digitized in terms of its content (e.g. historical, political, military etc), its type (e.g. chronologically, alphabetically etc),
- it lacks of guidelines for the way and the conditions of archiving the original material, as well as the digital content

Currently there has been an expression of strong interest for the exploitation of the digital archive from the local home office, the educational community and various local associations and organisations. The archive is at present accessible via the following web site <http://www.kaslas.blogspot.com> that aims to attract interest and complement with more information the current documentation, as well as to be used for educational purposes. To assist the later currently the digital archive is processed in order to be distributed in an "Interactive Historical Case" to schools to complement the educational content.

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## ESCIDOC - A SERVICE INFRASTRUCTURE FOR CULTURAL HERITAGE CONTENT

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### ABSTRACT:

The eSciDoc project ([www.escidoc.org](http://www.escidoc.org)) provides an open source infrastructure for scientists to store, preserve, retrieve and work with research-based data, including cultural heritage content. Since multiple requirements demand a broad set of re-usable, generic, and flexible components, it is designed and developed as a service-oriented architecture. In addition, community-specific solutions built around the services allow user- and research-focused working environments. The heterogeneity of research questions, tools, workflows, and primary data, as well as traditional forms of publication required us to focus on supporting multiple content models and descriptive metadata formats, together with common functionalities such as persistent identification, adequate versioning and management of primary data, aggregation of data, annotations, and access control. The underlying Fedora repository, enriched with the eSciDoc core services layer, allows for management and structuring of data at different levels of granularity - from basic items to complex aggregations of data. In the course of the DARIAH project, our institution and our partners aim at building a pan-European research infrastructure based on Fedora/eSciDoc. This infrastructure will enable transparent access to and management of digital content across all participating museums, libraries and other institutions in the arts and humanities sector. In our paper we will focus on the benefits of eSciDoc's data and content modelling and of building a sustainable technical infrastructure. In addition, we will describe the current project approach and the current requirements regarding cultural heritage content.

### 1. INTRODUCTION

eSciDoc ([www.escidoc.org](http://www.escidoc.org)) as a joint project of the Max Planck Society (MPG) and FIZ Karlsruhe, is funded by the German Federal Ministry of Education and Research (BMBF). The aim of the project is to provide a scholarly communication platform for multiple disciplines, developed as open source to be re-used by any interested research organisation.

Due to the challenges of emerging eScience scenarios, services, solutions and tools developed will have to handle research results as well as primary data, in order to support distributed and interdisciplinary research questions. Designed in a modular and complementary way, the infrastructure will provide effective, reliable and comprehensive access to data and information. The solutions on top are designed as user-centered working environments, focusing on a specific research scenario and serve as tools for visualising, managing, publishing and enriching their artefacts. (Dreyer et al. 2007)

### 2. PROJECT APPROACH

The 80 institutes of the Max Planck Society act as main stakeholders in the development of the eSciDoc project. Given the variety of disciplines and hence the multiplicity of data formats and information entities, the set of institutes provides a vivid panopticum of current and latent research scenarios, and poses challenges to introduce corresponding support of information technology.

In a close and ongoing exchange with the institutes, our institution is actively monitoring and identifying current

requirements from scientists, which vary from publishing digitized artefacts to adequate solutions for handling the scientific lifecycle of experimental data. Understanding the main research questions behind a scientific information lifecycle, identifying the level of dynamic interaction envisioned by scientists that is required as a basis for analyzing artefacts, and knowing about their formats and the processes within the scientific information lifecycle, that is the starting point for being able to identify generic components and processes for eSciDoc. Another important aspect is business process modelling, i.e. to describe organisational aspects, which is interdependent with identifying services and solutions needed, i.e. technical aspects.

This approach supports the overall project development, as with each new solution we gain insight into generic requirements for the infrastructure and into necessary "add-ons" that are specific to disciplines or certain types of research data.

Therefore, the complete development life cycle facilitates reflection and buildup of know-how on open and sustainable formats, semantic relations between artefacts and their constituent parts, as well as aspects regarding authorisation, persistent identification, data curation and long-term archiving.

### 3. REQUIREMENTS FOR CULTURAL HERITAGE

#### 3.1 Context Max Planck Society

Within the MPG, several institutes are hosting distinguished holdings of digitized cultural heritage collections. The *Max Planck Institute for the History of Science* ([www.mpiwg-](http://www.mpiwg-)

berlin.mpg.de) has done important work in organizing and providing a platform for more than 70 seed collections on European cultural heritage collections (ECHO echo.mpiwg-berlin.mpg.de). The *Kunsthistorisches Institut Florenz KHI* (www.khi.fi.it) and the *Bibliotheca Hertziana* (www.biblhertz.it) in Rome provide important holdings in their photo libraries as well as digitized engravings or architectural drawings. The *MPI for European History of Law* (www.mpier.uni-frankfurt.de) provides digitized historic journals.

Most of the institutes have already undertaken considerable efforts – on their own or together with partners – for digitization of their material, to some extent in high-resolution quality, and to some extent even within very sophisticated viewing environments. However, most solutions are lacking sustainable and interoperable environments to store and extend their collections. The provision of reliable and open access to valuable resources largely depends on funding, personal enthusiasm and technical expertise, which is not easy to find and retain. The transition from mere publishing to provision of interactive working environments is often limited up to now with respect to annotating, semantic linking, individual compilations or adding new media types.

The eSciDoc project tries to address these aspects by providing an infrastructure which can be used to support and/or substitute locally developed solutions. Consequently, the eSciDoc infrastructure and its services can be used for cooperative working environments and management of content, as well as a mere archive solution for content managed in external systems. In addition, some services can be integrated into external applications, independently from the overall eSciDoc infrastructure. Staying agnostic to data, technologies, and data structures in the design of the logical infrastructure enables us to react quickly to new content, data formats, and functionalities.

Thus, the aim of the project is not only to provide solutions for cooperative working environments, but in addition to create a stable infrastructure to advance accessibility, dissemination, as well as re-purposing and mashing-up of data across disciplines.

### 3.2 International context - DARIAH

The DARIAH project aims at creating a pan-European research infrastructure for the arts and humanities. DARIAH intends to provide seamless access to distributed data holdings across Europe and aims at enabling integration into national research infrastructures. In this respect, eSciDoc represents a core reference technology for archiving, managing and disseminating scientific publications, primary sources and secondary documents in the humanities. This in turn poses several requirements on eSciDoc. Firstly, eSciDoc has to provide comprehensive access control mechanisms across distributed data holdings, e.g. via Shibboleth. Secondly, resources in the arts and humanities can be highly diverse with respect to content and data formats and are often interlinked. Therefore, a content and relation model that allows capturing scientific and scholarly work processes as well as modeling their complex webs of documents and data types has to be provided. Thirdly, DARIAH intends to capture also the semantic connections between the digital objects within the connected repositories. Hence, eSciDoc has to provide interfaces for services that link between representations of repository object models and corresponding ontologies.

Fourthly, eSciDoc has to be interoperable with national research infrastructures. One crucial predicament about offering a corresponding interoperability service layer for external initiatives is the agreement about – and utilization and documentation of – standards for data-exchange and access.

### 3.3 Current eSciDoc solutions in the context of cultural heritage

The solution VIRR ("Virtueller Raum Reichsrecht") is an example for the common scenario of publishing the corpus of digitized artefacts like images and texts. VIRR provides a digital compilation and working environment for various artefacts of the period of the Holy Roman Empire, and is developed together with the MPI for European History of Law. (Please visit [colab.mpg.de/mediawiki/ViRR:\\_Virtueller\\_Raum\\_Reichsrecht](http://colab.mpg.de/mediawiki/ViRR:_Virtueller_Raum_Reichsrecht) for more information. The first prototype is available under [faces1.mpg.de:8080/virr\\_presentation/](http://faces1.mpg.de:8080/virr_presentation/).) In the first phase we focus on the publication of the artefacts. Structural navigation through the scanned textual resources (collection – multivolume – volume – chapter – page) with respective metadata is provided; the current viewing environment will be improved, the improvement will be based on the DigiLib\* tool. In a second phase we will focus on developing an interactive working environment, while the collection will be indexed, edited, and enlarged cooperatively by scientists and trained staff.

Research focused on text-based publications requires the possibility of enriching publications with information on text-inherent structures. We therefore have to support generation and storage of XML transcriptions of the fulltext (e.g. TEI). For an adequate working environment, the user needs to have the option to combine the viewing environment with an editing environment (e.g. zooming in on a part of a scan and enriching the focused part with annotations). In this context, versioning, persistent identification, and the possibility to annotate publications and their constituent parts must be supported.

Complementary to VIRR, the solution FACES offers a web-based collection of image data, containing facial stimuli, and is developed in conjunction with the MPI for Human Development. (Please visit [colab.mpg.de/mediawiki/Faces](http://colab.mpg.de/mediawiki/Faces) for more information. The initial prototype is available under [faces.mpg.de](http://faces.mpg.de).) The images have corresponding metadata and attributes and can be used for individual or project-specific research questions, for example by filtering and sorting them into individual subsets, which can be published and shared. As the images are the basis for multiple research questions (e.g. rating studies in the context of human development or neuroscientific research), the collection might be extended with new images, and images might be enriched with new metadata and attributes. Appropriate authentication and authorization mechanisms have to be provided to support potential legal constraints. In addition, the viewing environment must enable detailed analysis of the facial stimuli. In the meantime, the solution has raised interest at some other institutes with a need for an image-handling solution (and with quite diverse content, such as digitized photographs or microscope images).

\* DigiLib is a web based client/server technology for viewing and working with images. This open source software was jointly developed by the Max-Planck-Institute for the History of Science, the University of Bern and others. More under [colab.mpg.de/mediawiki/Digilib](http://colab.mpg.de/mediawiki/Digilib)

## 4. THE ESCIDOC INFRASTRUCTURE

### 4.1 Data and content modelling

Understanding the structure and the nature of the content resources was essential for the ability to meet the emerging requirements within the project. The first step was to define a general data model to support functionalities such as versioning, persistent identification, relating and annotating resources, and authorization. The second step was to refine the model by analyzing various types of resources to support characteristics specific to certain disciplines, institutions or resources (Tschida, Bulatovic 2008). Content resources are defined by two generic object patterns: Item and Container (Figure 1). An Item resource consists of metadata records (e.g. SISIS MAB record, MODS record, Dublin Core record) and optionally of components that represent the actual content (e.g. PDF file, JPEG file, XML file). A Container resource is an aggregation of other resources that allows grouping of other items or containers. Like the Item resource, Container can be described by multiple metadata records. In addition, each resource is maintained in a single administrative Context. Context resources are created by organizations (e.g. a project group) in accordance with their needs to express rules for content creation, update, quality assurance of metadata, dissemination, preservation, authorization policies, submission policies, etc.

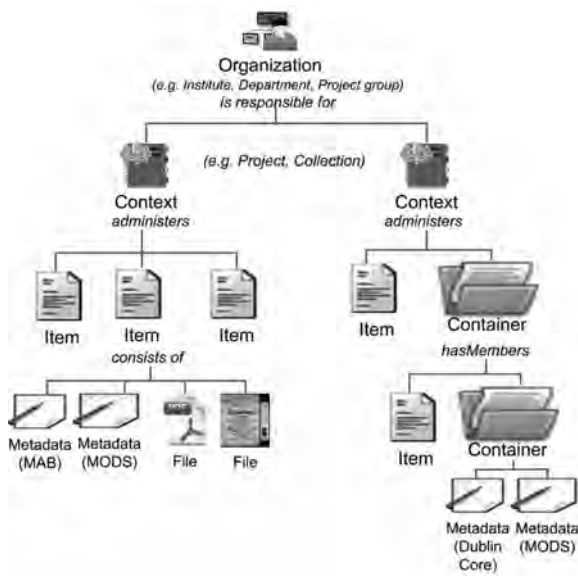


Figure 1: eSciDoc data model

Content models are formal representations of discipline-specific data models such as an integrated image and text view of primary sources or a precisely documented collection of images. For example, a digitized book can be expressed as a container of book page items and related transcription items. The book container (Figure 2) has bibliographic metadata based on the MODS metadata schema. Each page item consists of the digitized image of the page and a metadata record. The metadata record is inherited from the book container metadata. In addition, it has metadata containing the page number (e.g. 1, 2, 3, 4 or I, II, III, IV), chapter information etc.

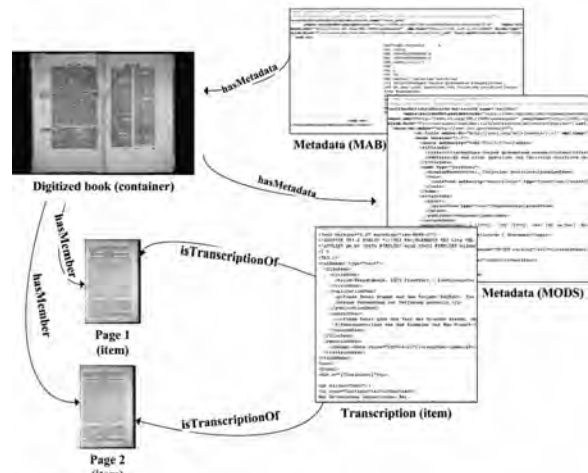


Figure 2: Visualization of the Digital Book content model

Relations between resources (e.g. structural relations within collection, kinship relations) are defined with respective relation ontologies. They are applicable to any kind of content managed in the digital repository. The content model defines which relation ontologies (and types of relations) can be used to relate the resources. For example a digitized book allows relations such as *hasMembers* (between book container and each page item), *isTranscriptionOf* (between transcription item and a page item).

By applying these mechanisms the eSciDoc infrastructure is able to easily adopt new types of resources in a standardized manner. In addition, this approach fosters the exchange of data and the reuse of resources for different purposes.

### 4.2 Services and service layers

The eSciDoc infrastructure is designed as a service-oriented architecture (SOA). Services are grouped into three service layers: core services, intermediate services and application services.

**Core services** implement basic CRUD operations on resources managed by the infrastructure. In addition they support the basic lifecycle of resources by a set of task-oriented operations such as submit, release or withdraw. Core services add value as they implement the functionalities such as versioning and persistent identification. Services involved in this group are Object Manager (Item, Container and Context handlers), Organizational Units Handler, Semantic Store Handler, Role Manager, Content Model Handler and User Account Handler.

**Intermediate services** represent both a service requestor and a service provider within the eSciDoc SOA. They act as adapters and façades to the basic services or provide additional functionality. Intermediate services can additionally manipulate their own data. Services involved in this group are Validation Service, Duplication Detection, Technical Metadata Extraction, PID Handler, Statistics Manager and Digilib.

**Application services** may combine services from all layers and implement business logic from a solution-specific domain. They are candidates for future process-centric services enabling service orchestration. Services involved in this group are Depositing Service, Publishing Service, Citation Style Manager, SearchAndIndexing, SearchAndOutput and Export Manager.

**Authentication and authorization.** The infrastructure implements distributed mechanisms for authentication and authorization. It is based on Shibboleth (Shibboleth, 2008) and XACML (OASIS, 2005) to define authorization policies. This approach enables integration with external identity management system such as LDAP. Service requests are protected by a security interceptor which forwards the request further to the Policy Decision Point (PDP) engine. The PDP engine evaluates the requests and authorizes clients, or prevents clients from performing the service operation requested. Policies can be defined for various levels of resource granularity, e.g. Organizational Unit, Context, Item, Container or File.

**Persistent identifiers.** Resources can be persistently identified at different levels of granularity. An item that consists of an image and metadata records can be persistently identified as a single resource. In addition, the image itself can be persistently identified. The infrastructure allows for assignment of persistent identifier to a resource at different stages of the internal lifecycle of a resource: during creation, modification or publishing. A persistent identifier can be assigned to a selected version, or to all versions of a resource separately. The choice of a persistent identification system (PID system) to be used is left to the user, i.e. the infrastructure is designed to provide an interface to a PID system preferred by a user. By now support of the Handle System (Sun, Lannom, Boesch, 2003) has been implemented.

#### 4.2.1 Example: Validation Service

Content models define the overall structure of the resources and the metadata schema that can be used to describe them. Validation Service goes a step beyond and allows for the definition of additional sets of constraints a resource must conform to in a specific context and at a particular stage during its lifecycle. Examples of such constraints are:

- A transcription cannot be created without at least one author
- A transcription cannot be published if the page item is unpublished.
- If a publisher name is given, the publication year must be given as well.
- If a resource is a journal article, the journal name must be added.
- All publications of a project group collection must have at least one author affiliated to that project group.

Validation Service introduces the concept of a validation schema to group a set of constraints that belong together. The validation schema includes validation points to define when a certain constraint should be checked (e.g. during creation, for a user-defined event or when publishing a resource). Validation Service allows for multiple validation schemas for a content model. This enables different organizations to have different criteria for, for example, the quality of the metadata while still reusing the content models defined once. For instance, project

group X may define constraint b) from the example above as restrictive during content creation. Project group Y may completely ignore this constraint. In this sense, project group X and project group Y work with different validation schemas for transcriptions. The selection of a validation schema to apply is a matter of configuration of the administrative Context (see paragraph 4.1) within the eSciDoc infrastructure.

At present two types of constraints are supported: informative or restrictive. For input it accepts a representation of a resource and produces a validation report in XML format as output.

If during the validation process a constraint is not fulfilled, the service provides an exception message with an identifier and an XPath pointer (XPath, 1999) to the exact position where validation failed. The use of the identifier for exception messages enables providing user-friendly (internationalized) messages to end users via a graphical user interface.

Validation Service can be used completely independently from other services in the infrastructure. Internally it uses Schematron (Schematron, 2008) for definition of validation schemas. The service is offered via three interfaces: EJB3 (Enterprise Java Bean), SOAP and REST.

#### 4.2.2 Example: SearchAndOutput

SearchAndOutput is a service that supports searching and exporting search results in a specific format, such as Endnote, APA citation style, eSciDoc native format enriched with a citation style output, or comma separated values (CSV) format. It enables, for example, exporting a digital collection of FACES images (at a resolution selected) together with their metadata in a single request. It is built as a service composition of three other services: SearchAndIndexing, Citation Style Manager, Export Manager.

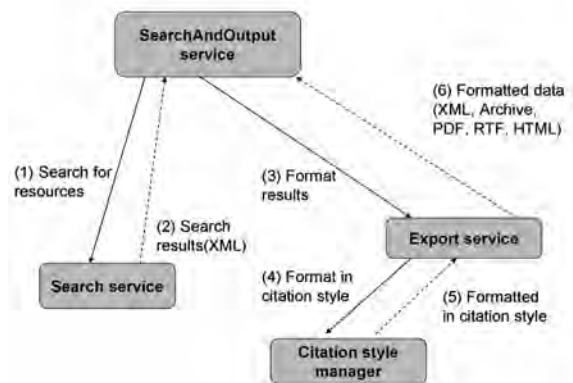


Figure 4: SearchAndOutput and service composition

Services are called in the following manner: A client issues a service request to SearchAndOutput specifying its search criteria, desired export format (APA style, EndNote format, CSV format), desired output format (PDF, HTML, RTF) and optionally an archival format (zip, gzip). SearchAndOutput invokes the search operation of SearchAndIndexing with the specified search criteria and output format parameters. Once it has retrieved the search results, it sends them to Export Manager (including the desired output format) as parameters.

Export Manager formats the results in accordance with the parameters conveyed, and sends the formatted data back to SearchAndOutput. The latter then forwards the formatted data to the service requester. Optionally, Export Manager may send a request to Citation Style Manager (if the data is requested to be formatted in a defined citation style). The service interface of SearchAndOutput is available via REST and EJB3 interfaces.

While Export Manager and Citation Style Manager can be used as completely independent services, SearchAndOutput is loosely coupled with the SearchAndIndexing. To relate it to another search service one needs to change the configuration properties and provide a transformation of input data into a format (XML) supported by SearchAndOutput.

### 4.3 Technical architecture

The eSciDoc infrastructure is based on the FedoraCommons (Fedora Commons, 2008) platform and other open-source software packages, such as PostgreSQL, JBoss application server, Lucene, Tomcat, JHove. The FedoraCommons platform provides the repository, preservation and semantic services the eSciDoc infrastructure services are built on. The eSciDoc infrastructure adds value by contributing object patterns, a content model, a versioning model, implementation of the basic lifecycle of content resources, referential integrity, interfaces to persistent identification systems, fine-grained access control as well as the possibility to define new relation ontologies on top of the Fedora base relation ontology.

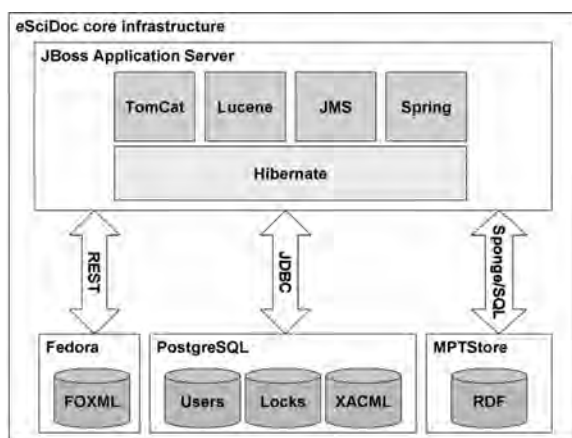


Figure 3: Core technical architecture of the eSciDoc service infrastructure

Figure 3 depicts the core technical architecture of the eSciDoc infrastructure. Being designed as a service-oriented architecture, the infrastructure does not prescribe the technology in which a new service or a solution can be developed. Service operations are offered via REST and/or SOAP interfaces (depending on the service). Some services are exposed as Enterprise Java Beans (EJB3) to accelerate the internal development where necessary. However a new service or solution that needs to use other services can be added independently of the programming language in which other services are built. Also the internal data structures of a programming language are not a limiting factor since the service input and output messages are formatted as XML data. Services within the eSciDoc infrastructure are built keeping this notion of independence from specific technologies in mind, even when they communicate among one another.

Another advantage of the service-orientation approach is the possibility to modify the service implementation in a process transparent to service users. This is especially useful when adding new functionality or extending the existing one. Service users need not be overburdened with the internal implementation of the service. They may rather focus on the functionality offered by the service, on input and output service messages, i.e. on service input and output data.

## 5. DIGITAL PRESERVATION ASPECTS

Preservation of digital content is a basic requirement that has to be fulfilled by any system managing this type of content. The eSciDoc infrastructure has been designed and implemented as a system that strongly emphasized issues related to the digital preservation.

- Internal format of data: All content resources are stored as Fedora FOXML documents. Thus the structure and description of each resource is readable by any human or machine user.
- Contextual information on what the data actually represents, for example, a publication or transcription of a scanned book page, is provided with a content model. Each resource references a content model resource. A content model is itself defined as a FOXML document.
- Resources are validated in accordance with rules that are not defined by the implementation logic but described by Schematron which is itself an ISO standard (ISO/IEC 19757-3:2006, 2006).
- Even though the eSciDoc infrastructure does not impose a metadata schema in use, it strongly recommends using open metadata standards wherever possible. As a minimum, content resources have a Dublin Core metadata record associated with them.
- Persistent identification of resources is eventually enforced when the resource is published. Users may decide what to identify (resource or resource version) and when to assign the persistent identifier (during creation, updates, or publishing). Additionally, if a resource already exists on an external system and if it has a persistent identifier assigned, the eSciDoc infrastructure keeps track of it.
- Technical Metadata Extraction Service based on the JHOVE - JSTOR/Harvard Object Validation Environment extracts the technical metadata from a set of text, audio and image formats (JHOVE, 2007). In addition it creates a PRONOM identifier for files (PRONOM, 2008) associated with the content resources.
- Each resource is associated with PREMIS metadata (PREMIS, 2008) that holds richer information on the version history and events in addition to the natively provided Fedora audit trail.
- All software components used are open source. Software delivered by the eSciDoc project is open source itself, and is available under the CDDL license (eSciDoc License, 2008). Documentation is also available to the public.

Digital preservation becomes increasingly complex when it has to deal with the management of content that is continuously updated. This is especially true for research and collaborative environments, where there is a tendency towards publishing results as early as possible. The eSciDoc infrastructure defines a basic workflow for all content resources, to enable better selection and general quality of resources that need to be

preserved. In this manner it supports the OAIS reference model (OAIS 2002).

By using open standards and open source components, the eSciDoc service infrastructure benefits from community developments in the area of digital preservation. The work in general is not finished and there are many initiatives in the arena.

## 6. CONCLUSIONS

The provision of digital artefacts relevant for the cultural heritage requires an understanding of their potential of being reused and re-purposed. Publishing digitized resources is not the aim, but the medium to facilitate new research and discourse – however, only if relevant structural, semantic, and cognitive entities can be modelled and described in a machine-readable way. We are approaching the development of a content model ontology and corresponding knowledge bases of resource descriptions. That allows for interoperability between various repositories, i.e. internal object models and the cross-validation of related resources. In that context, we will have the first proof of concept during the DARIAH project, where the eSciDoc infrastructure will serve as demonstrator platform.

In addition to sustainable data and content modelling, the requirement for sustainable technical infrastructures is of high interest in the humanities to avoid “buried treasures” and isolated collections in an increasingly interdisciplinary and globalized environment. Furthermore, the advance in virtual organisations leads to increasingly sophisticated requirements for handling users and their respective rights to access and enrich shared artefacts.

We will continue to work on solutions, services and tools to support sustainable access to the data holdings of the Max Planck institutes, and we are convinced that the overall design facilitates the support of multiple types of cultural heritage content.

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# **CH Digital Documentation and Communication**





## A WEB BASED GIS FOR THE BYZANTINE CHURCHES OF CYPRUS

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**KEY WORDS:** Geometric recording, Cultural heritage, Web-based GIS, Google Earth, 3D modelling, Visualisation

### ABSTRACT:

This paper describes the design of a Monument Information Database and its implementation in a web based environment. The object concerns the ten painted Byzantine Churches of Cyprus, located in Troodos Mountain, a UNESCO World Heritage List item. For the purposes of a larger inter-state project between Greece and Cyprus under the name of APHRODITE, as much information as possible was collected for the ten churches. This wealth of data has been organized in a database, in such a way to enable access of this information also from within web applications, such as e.g. Google Earth. This Monument Information System (MIS) has been developed to provide a wealth of qualitative and quantitative information to the user. The system caters for the collection, archiving, processing, management of any kind of information and virtual touring using multimedia technology. The 3D models of the churches have been constructed using the Google Sketch-Up utility, with the help of some elementary measurements in situ. The 3D models were uploaded to the official site of Google 3D Warehouse – Models. The user can find the monuments by just searching using appropriate key-words where one can read some main characteristics of the monument. For further information the user may click at the link for the web site that is currently developed for this purpose. Moreover, the user has also the possibility to virtually fly over the area of interest based on suitably draped satellite images. The monuments are accurately georeferenced and appear in their exact position.

### 1. INTRODUCTION

The geometric documentation of a monument is defined as the action of acquiring, processing, presenting and recording the necessary data for the determination of the position and the actual existing form, shape and size of the monument in the three dimensional space at a particular given moment in time. Geometric documentation should be considered as an integral part of a greater action, the General Documentation of the Cultural Heritage. This comprises, among others, the historical documentation, the architectural documentation, the bibliographic documentation etc. All this wealth of information is usually stored, i.e. archived, in many forms. In the previous years analogue forms of archiving were employed, such as special monument cards. However this practice, although complete in its way, did not ensure the storing of the interrelations of the information and did not relate the information to the position of the monument. Today, not only the use of digital relational databases but also the role of Geographical Information Systems (GIS) in the field of Cultural Heritage is recognized as important in conservation, protection, analysis, development and management of archaeological sites and monuments (Ioannidis et al, 2004). The compilation of specialized GIS in order to accommodate all pieces of information related to a monument led to an electronic form of Monument Archives, the Monument Information Systems (MIS).

Contemporary techniques and methods of Information Science, Computer Graphics, Virtual Reality and Multimedia Technology are developed and integrated in order to record, represent and protect Cultural Heritage. Geometrically correct 3D reconstructions have lately become feasible by the integration of laser scanner and photogrammetric data. These geo-referenced products may become available within a web portal to those interested (students, researchers, scientists, tourists). The role of the Internet for the knowledge and sharing

of multi-dimensional data is fundamental. Web GIS is the perfect way to share geographical information, allowing the user to view raster and vector information in overlay, to load and unload, query, compare data in a simple way, through a browser. Three dimensional geographical data inside 3D environments (3D WebGIS) or web-based 3D reconstruction of cultural heritage objects and artifacts (Vergauwen and van Gool, 2006) and 4D GIS with the additional time-component dimension strictly connected to archaeological and historical data (e.g., TimeMap<sup>TM</sup> software - <http://www.timemap.net>; Hosse and Schilcher, 2003) can be managed by using more sophisticated procedures.

During the last years the development of software for the management and presentation of geo-data has been rapidly increased. It is mentioned that there are more than 550 pieces of software available for terrain visualization ([http://www.tec.army.mil/TD/tvd/survey/survey\\_toc.html](http://www.tec.army.mil/TD/tvd/survey/survey_toc.html)) and a variety of software (ArcGIS/ArcView<sup>TM</sup>, VirtualGIS<sup>TM</sup>, Skyline<sup>TM</sup>, TerrainView<sup>TM</sup>, Maya<sup>TM</sup> etc) for visualization and 3D GIS. Also, the 3D Engines, which is specific software that combines earth 3D model, images and vector data, is used for an ever increasing range of applications, among them cultural heritage management. These systems are freely distributed and include data from various space agencies (e.g., EuroImage, DigitalGlobe, NASA, WorldSAT etc), a 3D (which in reality is a 2.5D) or a 2D viewer and streaming technology. Some examples are:

- Google Earth<sup>TM</sup>, a 3D viewer with Quickbird high resolution satellite images in some areas and 3D city models of some cities
- NASA Wind<sup>TM</sup> (<http://worldwind.arc.nasa.gov/>), a 3D viewer of the NASA Blue Marble and Landsat data, terrain model from SRTM mission and high resolution satellite images over USA

- EarthSLOT Web Interface™ ([http://eslot.engr.uaf.edu:8181/eslot\\_web\\_interface.html](http://eslot.engr.uaf.edu:8181/eslot_web_interface.html)), a 3D viewer of the NASA monthly data using Skyline 3D engine
- VirtualEarth™, a 2D viewer with satellite data and aerial images over USA
- GeoFusion™, Yawaha™, etc.

Most of these systems provide additional low cost commercial tools, like Google Earth Pro™ and Google SketchUp Pro™, ArcGlobe™ of ESRI, TerrainGlobe™ of Viewtec, etc, where the user can import his own data, such as 3D models, vector layers and descriptive information.

The use of open source software in cultural heritage management, in particular for non profit organisations and research centres, gives public access to a wide community of users to spatial cultural data. Several applications of open source web GIS are mentioned in international literature, such as the *Appia Antica Project* (<http://www.appia.itabc.cnr.it>) for the creation of a 3D spatial archive of the monuments of a wide archaeological park in Rome, through intense mapping, GIS and modelling activities (Pescarin et al, 2005), using MapServer™ software (<http://mapserver.gis.umn.edu>) and OpenSceneGraph™ (<http://www.openscenegraph.org>).

In this paper the process for the production of 3D reconstruction of historic monuments and their integration with the necessary attributes (historic information, images, etc.) in the web is described. The proper methodology for easy creation and presentation of 3D models, using Google Earth Pro and Google SketchUp software is developed. An application is made for the Painted Byzantine Churches of Troodos Mountain in Cyprus, which are included to the UNESCO list of World Heritage Monuments.

## 2. THE PROJECT “APHRODITE”

National Technical University of Athens and the Higher Technological Institute of Cyprus undertook an inter-state research project between Greece and Cyprus, which has been jointly financed by the General Secretariat of Research and Technology of Greece and the Research Promotion Foundation of Cyprus. The objectives of this project, code named “Aphrodite”, were the design of a Monument Information System (MIS) and its implementation in a web-based environment, for the 3D accurate reconstruction, using contemporary geodetic measurements, photogrammetric procedures and terrestrial laser scanners, documentation and archiving of historical monuments.

An application of the method was made for Painted Byzantine Churches of Troodos Mountain in Cyprus (Figure 1), which are dated from the 11th to 14th century AD. The region of Mountain Troodos is characterized by one of the largest groups of churches and monasteries of the former Byzantine Empire. The complex of 10 monuments, which all are richly decorated with murals, provides an overview of Byzantine and post-Byzantine painting (frescoes religious painting) in Cyprus. They range from small churches, such as the Church of Virgin Mary in Asinou, whose rural architectural style is in stark contrast to their highly refined decoration, to monasteries as St John Lampadistis (<http://whc.unesco.org/en/list/351/>). These churches, unique monuments of Byzantine architecture and religious art, were inscribed to the UNESCO list of World

Heritage Monuments since 1985. UNESCO’s criteria were both the architecture, the landscape design but also the fact that these monuments are “exceptional testimony to a cultural tradition”.

These ten churches are:

- Church of Ayios Nikolaos tis Steyis at Kakopetria
- Ayios Ionannis Lambadhistis Monastery at Kalopanayiotis
- Church of Panayia Phorvotissa (Asinou) at Nikitari
- Church of Panayia tou Arakou at Lagoudhera
- Church of Panayia at Moutoullas
- Church of Archangelos Michael at Pedhoulas
- Church of Timios Stavros at Pelendria
- Church of Panayia Podhithou at Galata
- Church of Stavros Ayiasmati at Platanistasa
- Church of Ayia Sotira of the Transfiguration of the Savior, “*tou Soterou*”, at Palaichori (this church was included to the UNESCO list in 2001).

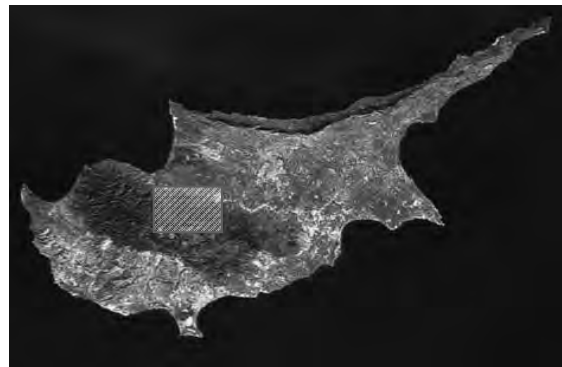


Figure 1: The region of Mountain Troodos in Cyprus, where the complex of 10 churches which are included in the UNESCO list of World Heritage Monuments

## 3. METHODOLOGY

First an accurate three dimensional digital reconstruction of the Painted Churches (buildings and surrounding area) at a large scale and their virtual tour and guidance in a multimedia environment is made. For the exact three dimensional reconstruction contemporary photogrammetric and terrestrial laser scanning techniques are employed, combined with virtual reality methods and multimedia techniques. The system under development is based on and contains a multitude of innovative research procedures in the field of three dimensional reconstructions, in the field of virtual and graphic representation and also in the field of personalized and adapted guidance and navigation.

Initially classical and standard database software was employed for the creation of the information system, namely MS Access. A suitable entity-relation table (Figure 2) was developed in order to interrelate the various pieces of information for each monument. Moreover a user friendly interface was designed in order to enable data entry to the data base (Figure 3). The data base was design to contain all possible pieces of information related to a monument as described above. A suitable interface for operation of the whole data base as a web application eas also designed. However this was considered as quite heavy to

expose to the web due to the large size of the files necessary to operate.

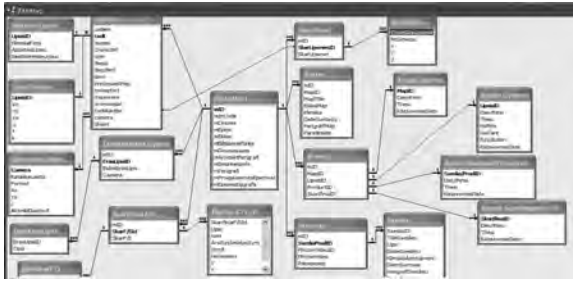


Figure 2: The E-R table of the MIS



Figure 3: MS Access database interface

Then a Monument Information System was developed in order to be easily exposed to the web, while at the same time able to provide a wealth of qualitative and quantitative information. The system caters for the collection, archiving, processing, management of any kind of information and virtual touring using multimedia technology. The user also has the possibility to virtually fly over the area of interest based on suitably draped satellite images. The monuments are accurately georeferenced and appear in their exact position.

Among the alternative options, for 3D modeling over the web, provided by the available free or commercial software, the use of Google SkethUp was selected. This software based on the freely distributed and extremely popular Google Earth environment and has been used successfully with a number of archaeological applications (see <http://www.gisarch.com/category/sketchup/> for applications like "Archaeology and 3D model of Areca Mill", "Archaeology viz with Picasa, Google Earth and SkethUp", "Egypt archaeology in Google Earth", etc). The commercial tool Google SkethUp Pro 6 provides not only the standard facilities of free tool Google SkethUp to create, export and present 3D models, but also the capability for rendering and exporting the models into CAD (or using various formats, e.g., dxf, 3ds, obj, xsi, fbx, eps, pdf, vrml, kmz) as well.

The system may operate either autonomously or in the web through the Google Earth environment. In this way the result is a unique product of virtual realism for the visualization of

cultural heritage objects, while at the same time it is able to provide virtual touring services adapted to the users' needs.

#### 4. IMPLEMENTATION

A Monument Information System (MIS), which allows both collection and storage of any data related to the monuments, was created. This MIS combines spatial and non-spatial information. Spatial characteristics can easily be extracted from MIS, either from the 3D photorealistic visualization of the area or even from the 3D coordinates of the Byzantine churches. Non-spatial information is related to each monument through tables of attributes (Figure 4). Through these tables any kind of information, such as historical, architecture, information about opening hours, web sites related to churches etc. (Figure 5).

ID	Name	Location
1	Church of Panagia (The Virgin)	Katoliki
2	Church of Acothangelos (Archangel Michael)	Katoliki
3	Church of Panagia (The Virgin)	Katoliki
4	Church of Acothangelos (Archangel Michael)	Katoliki
5	Church of Panagia (The Virgin)	Katoliki
6	Church of Acothangelos (Archangel Michael)	Katoliki
7	Church of Panagia (The Virgin)	Katoliki
8	Church of Acothangelos (Archangel Michael)	Katoliki
9	Church of Panagia (The Virgin)	Katoliki
10	Church of Acothangelos (Archangel Michael)	Katoliki

Figure 4: Attribute table of the monuments

The interface designed for the operation and interaction with the data base of the MIS enables the user to search through the stored information via various channels: Either by the name of the monument, or by pinpointing its location on a map, or by entering suitable key words etc (Figure 6).

The next step was to provide the user with 3D information, i.e. provide the user with the opportunity to visualize the monument in 3D. This implies that such information is available, either through a rigorous procedure for 3D metric data acquisition employing accurate methods, such as surveying measurements, photogrammetric methodology or terrestrial laser scanning (Sophocleous et al. 2006), or using approximate methods employing mainly measurement of the basic dimensions of the monument. This latter method was used in conjunction with the Google SkethUp<sup>®</sup> software, freely available, to produce the 3D visualizations, until a more accurate methodology was employed for this purpose.

The churches were sketched up using both simple photogrammetric procedures (like rectification) of each plane of a monument and measurements. The 3D wire frame result was a combination of lines, arcs, rectangles and circles (Figure 7). The design was made only for the outside facades of the churches and they were also shaded using the software's tools (Figure 8).

The texture of each church was extracted from recently taken photographs. Some main characteristics of each church (wooden doors, arches, UNESCO World Cultural Heritage label) were specially photographed, in order to achieve a more realistic result. For the rest of the church's patterns, either "sample material" was used or the whole facades or in some cases both. At this stage it should be reminded that the model's size had to remain low (i.e. lower than 10 Mb) for the real time rendering on the web to be feasible.

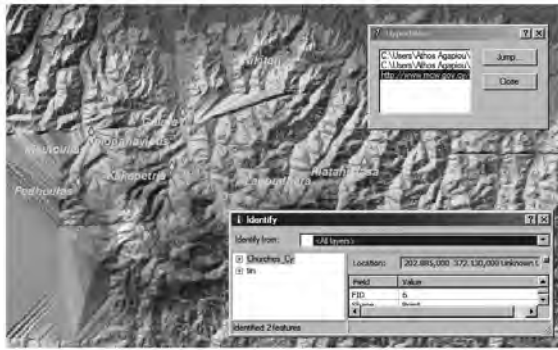


Figure 7: Wireframe sketch in Google SketchUp™



Figure 5: Spatial and non-spatial information as displayed in the same time at the MIS, like photographs or web sites (such as UNESCO official web site for the Painted Churches in the Troodos Region etc.)



Figure 8: Views of the rendered model in Google SketchUp™

These “light” models were initially georeferenced using Google Earth. Finally the model was design and modified according to its physical terrain, which was imported from Google Earth to Google SketchUp™ (Figure 9).



Figure 6: The MIS interface



Figure 9: The 3D model with the terrain

These models were then exported to Google Earth (Figure 10). The user has the possibility to fly over the area of each monument and can see the 3D models of the churches, in real time. Furthermore the user may be briefly informed about the history, the architecture of the monument and even take 3D measurements of the monument.

The 3D models (in Kml code for viewing in Google Earth and as SketchUp model) were uploaded to the official site of Google 3D Warehouse – Models (<http://sketchup.google.com/3dwarehouse>). The user can find the monuments by just searching using key – words (e.g. churches of Cyprus) where one can read some main characteristics of the monument. For further information the user may click at the link for the web site that is currently being developed for this purpose.

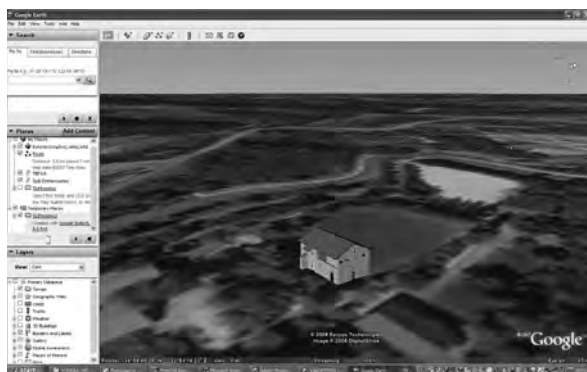


Figure 10: The 3D model of a church exported in Google Earth

Moreover the models can be found in Google Maps, a service of Google Company where someone can track the monuments through car tracking systems (with Google Map software provided), smartphones and generally for most web-enabled mobile phones. From such devices a user can sideload and synchronize (dynamically) the data through Google Maps.

## 5. CONCLUSIONS

In this paper both simple and more complex methods of designing a Monument Information System for managing Cultural heritage objects have been presented. 3D modeling, accurate documentation using terrestrial laser scanning and photogrammetric procedure, “light” models from free software and an application at a Monument Information System have also been considered for inclusion in the MIS, bearing in mind simplicity for running the application over the web.

These data can be exploited either autonomously or in real time on the web. Such technologies are now getting even more popular. The exploitation of 3D visualization of multi-source data has shortened the distance between reality and “virtuality”, it has enabled virtual 3D measurements and augmented reality through animation, integrating as much information as possible for the benefit of the final product.

The final product can have many uses from virtual realism for the visualization of cultural heritage objects, virtual touring services adapted to the users’ needs, for education purpose and many more. However it remains an invaluable tool in the hands of researchers, curators and everybody interested in Cultural Heritage.

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## LESSONS LEARNED FROM CULTURAL HERITAGE DIGITISATION PROJECTS IN CRETE

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**KEY WORDS:** 3D Digitising, Crete, Ceramics, Monastery Relics, Wooden Artifacts, Ancient Skull, Virtual Museum

### ABSTRACT:

This paper presents some lessons and experience gained from several cultural digitizing projects in Crete Island. Local Technological Institute introduced modern 2-D and 3-D digitizing technologies to various target groups, closely related with the rich cultural heritage of the island. These projects include 2D and 3D digitising of ancient ceramics, monastery relics and wooden artifacts, 3D modeling and FEM analysis of traditional local musical instruments, 3D modeling and 3D reconstruction of an ancient Minoan skull, recreation of the face of an ancient Minoan man and development of the virtual museum of San Salvatore. The familiarization of archaeologists, local authorities, museum experts, architects and others who worked in these projects with the potential usage and advantages of the new 3D digitising technologies was one of the most difficult and important results.

## 1. INTRODUCTION

### 1.1 Crete – An Island full of history

Crete is an island in the southern part of Europe and its strategic important location was the main reason for historically being first priority for many different civilisations and cultures.

Known history in Crete starts during the neolithic ages (6.000-2.600 BC) and continues with the famous Minoan Empire (2.600-1.100 BC) which established a naval empire in the Mediterranean during this period. Importing, processing and re-exporting of metal, together with intermediate trade, accumulated wealth to the island. During this time, art and science flourished. The Dorian years (1.100-67 BC) were marked by the first appearance of iron tools, and the deterioration of the Minoan Empire to various city-states. The Romans arrived in Crete at 67 BC as mediators but settled in as conquerors. Under Roman rule, which brought peace and some autonomy to the island, Crete enjoyed a period of prosperity, as many Roman remains show.

The island was part of the Byzantine Empire from 325 AD to 824 AD and then converted to Christianity. The Arabs also left their mark on the island, from 824 to 961 AC. Noble families from Byzantium, merchants from Europe and Christians from eastern countries settled in again and rejoined Crete with the Byzantine empire (961-1204 AD). They built 14 forts around the island and fought the Venetian fleet for four years before finally yielding in 1210.

The Venetian occupation lasted for 450 years (1204 - 1669 A.D.). The surviving Venetian fortifications and castles remain in good condition today. Many artists and scholars found refuge in Crete during the decline of the Byzantine Empire and after the fall of Byzantium itself. They established schools and Orthodox monasteries. Also literature and art flourished. Despite the Venetian influence, Cretan traditions continued.

Crete falls to the Turks in 1669. This occupation lasted until 1878 and then Crete remained autonomous until 1913 when it united with Greece. During the Second World War the Germans occupied the island for 4 years. Crete avoids worst of the following Greek civil war and then the first infantry steps in exploiting archaeological resources started.

### 1.2 Digitising Cultural Heritage of Crete

All these different civilisations and cultures left their mark on the island. A huge variety of archaeological sites and exhibits from this rich Cretan culture still remains. Furthermore the need for promoting this cultural heritage by means of multimedia applications and by improving processes like cataloguing, studying, preserving and replicating production has become more and more obvious (Maravelakis et al 2006).

2D and 3D digitising equipment of the latest technology provided by the local Technological Institutes of Crete combined with special trained personnel, initialised the process of digitizing the cultural heritage of Crete some years ago. As a result, a close cooperation with local authorities and archaeological foundations was established and some digitising cultural heritage projects started.

This paper presents some lessons and experience gained from selected cultural digitizing projects, run by two local academic institutes and a archaeological foundation: the Technological Educational Institute of Crete, the Technical University of Crete and the 28th Ephorate of Byzantine Antiquities. These projects include 2D and 3D digitising of ancient ceramics, monastery relics and wooden artifacts, 3D modeling and FEM analysis of traditional local musical instruments, 3D modeling and 3D reconstruction of an ancient Minoan skull, recreation of the face of an ancient Minoan man and development of the virtual museum of San Salvatore. One of the main goals of these projects was to become pilot projects in digitizing the cultural

heritage of Crete, a task that for sure needs more than one generation to be completed.

## 2. SELECTED DIGITISING CULTURAL HERITAGE PROJECTS IN CRETE

### 2.1 2D & 3D Digitisation of Ancient Ceramics

For this project the standard procedure of a digitising cultural heritage project was followed including:

- Development of an action plan: clear identification of targets, reassuring the appropriate resources needed, selection of the trained personnel, determination of an activities list
- Selection of the exhibits to be digitised
- Adjustment of the available environment for the digitisation process
- Selection of the appropriate equipment needed for the project
- Reassuring appropriate treatment for sensitive and easy to be damaged exhibits
- Selection of metadata and database
- Promotion of the digitised exhibits by means of multimedia applications
- Definition of IPR procedures

A collection of 500 ancient ceramics which came from various excavations and donations were selected. A set of 50 different ceramics were chosen for 3D digitising by 3D scanning. The collection was shared in two different environments: a museum (figure 1) and the archaeological laboratory of the castle of Firkas (figure 2). Different storing and lighting conditions, different time and space availability required a special digitisation approach for each location.

A special light box and white balancing was used in order to achieve uniform light diffusion and accurate colour recording. The Minolta Vivid 910 Vi non contact laser scanner was used to obtain the 3D geometry and texture of the selected ceramics. 3D output formats including contour lines of cross-sections, vml models and 3d nurbs models were produced (figures 3,4).



Figure 1: 2D digitising process in a museum



Figure 2: 2D digitising process in the castle of Firkas

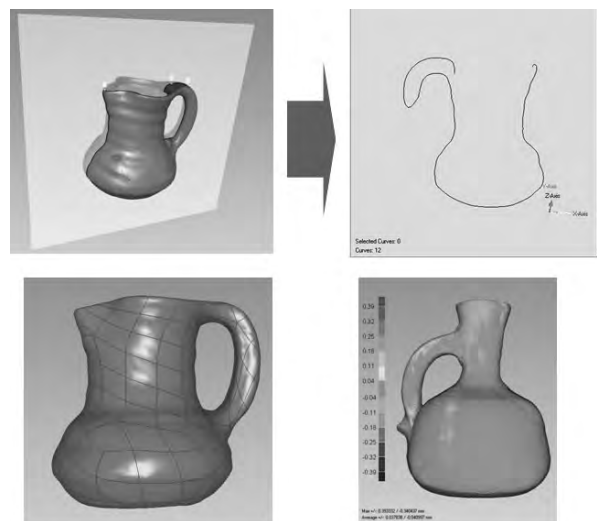


Figure 3: Different output format of 3D ceramic models



Figure 4: 2D photo and VRML representation of a fish form ancient ceramic



## 2.2 Monastery relics and wooden artifacts

In the island of Crete, there are more than 4.000 Churches and Monasteries. Monastery relics and wooden artifacts are used for the interior decoration of these buildings. Two of the most famous monasteries in Crete were chosen for digitisation: The monastery of Gonia in Kolimpari and the Monastery of Preveli (figures 5,6).

The exhibits selected for 2D and 3D digitisation included: icons, crosses, books, wooden temples and priest clothes (figure 7). Parts of wooden temples were also scanned for a twofold usage. Creation of 3D models and replica production (figure 8).

## 2.3 Traditional musical instruments

The most famous local musical Instrument in Crete is the “Cretan Lyra”. There are many “Cretan lyres” manufactures but only a few are famous for the quality of their instruments. This project had two main goals:

- To analyse and compare the acoustic properties of these instruments
- To see if modern 3D scanning and Rapid Prototyping techniques can be applied in order to have a replica with similar acoustic quality

Three of the most famous cretan lyra manufactures were chosen, and their instrument were scanned using the Minolta Vivid laser scanner. FEM analysis was used to analyse the acoustic properties of the instruments (Gymonopoulos et al 2006). An STL model was also created, which was used for the replica production with rapid prototyping (figure 8).



Figure 5: 3D scanning in Moni Gonias

## 2.4 Virtual Museum, case of San Salvatore

Very important archaeological material, gathered from excavations conducted by the 28th Ephorate of Byzantine Antiquities in the city of Chania, as well as from private collections and donations, has created a unique collection which is presented in the museum of San Salbadore. This collection, clearly records the historical course of the westernmost county of Crete from the first years of Christianity to, and including, the years of the Turkish occupation. Representative samples of this collection display an outline of the historic and artistic face of the county during the Byzantine and Post-Byzantine periods. The exhibits have been grouped according to type: mosaics,

tomb stone inscriptions, murals, icons, architectural sculptures, ceramics and coins.



Figure 6: Explaining the digitisation process to a monk



Figure 7: 2D photo and VRML model of a “Mitra”

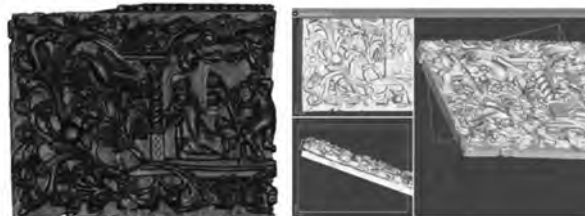


Figure 8: VRML and rapid prototype models of a wooden temple

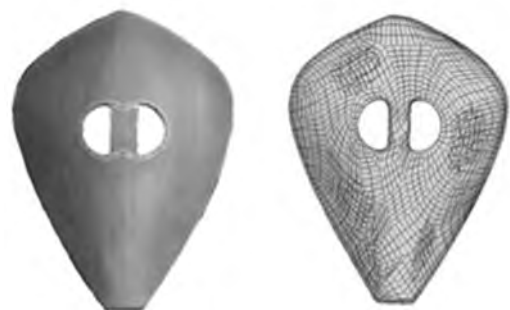


Figure 8: 3D model with texture and CAD model for FEM analysis of a Cretan Lyre

In this project Multimedia 3D visualising techniques were used in order to create a virtual representation of the museum. Special tripod head and fisheye lens were used to create spherical panoramas of the various rooms of the Museum. In addition 3D scanning techniques were used for the creation of 3D VRML exhibits which were linked with hotspots in the virtual panorama (figure 9). To our knowledge this is the first Virtual Museum in Greece with real 3D exhibits.



Figure 9: The virtual museum of San Salvatore

### 2.5 Recreation of Ancient Minoan Skull

Archaeological human bone findings are extremely rare and sensitive. One of the most challenging tasks in archaeology is to obtain the most information that we can get from for these findings, without destroying them.

An ancient Minoan skull of very archaeological importance was found in Crete (figure 10). The main aim in this project was to build an exact replica of this skull that could be used in all archaeological research activities, without using the real one and increasing the possibilities of destroying part or the majority of the skull. For this reason Computer Tomography (CT) scans were used in order to create the 3D model of the skull. Then a Dimension Stratsys SST 778 3D printer was used to get the physical replica prototype (figure 11).



Figure 10: The ancient Minoan skull

Going one step forward, according to archaeologists, (Poulianos, 1999), anthropologic features show that the modern population of Crete (in a sample of 3000 individuals) remained the same at least from the Minoan Period season and belongs in the native Aegean anthropologic type. Based on these studies and using special software on the 3D skull model, the face of the ancient Minoan Man was recreated (figure 12) (Sfakiotakis et al 2006).



Figure 11: Building an exact replica of the ancient Minoan skull in 3d printer



Figure 12: Recreating the face of the ancient Minoan man

## 3. LESSONS LEARNED - CONCLUSIONS

Our experience from digitising projects in the island of Crete, during the last 5 years revealed some interesting remarks and lessons.

### 3.1 General Lessons

- The familiarisation of archaeologists, local authorities, museum experts, architects and others who worked in these projects with the potential usage and advantages of the new 3D digitising technologies was one of the most difficult and important results.
- Virtual representation of 3D exhibits and the virtual Museum proved to be very attractive and useful to archaeologists and other users.
- There was a very good response from Local Authorities and municipalities to the potential usage of 3D technologies. New ideas like 3D digitising of castles, churches, walls and ancient ruins have been emerged and a great demand for new digitizing projects was shown.
- One of the important tasks for the virtual heritage system is how to manage the various kinds of cultural heritage assets (Kwon et al 2001).
- The task of digitizing the cultural heritage of Crete needs more than one generation to be completed.

### 3.2 Specific Lessons

- The rule in digitizing projects is that unexpected problems may emerge frequently. For example our digitizing team had very difficulties in finding time in the museum when no visitors were allowed. Monks in the monastery were not always so enthusiastic with our team disturbing their usual peace and time of isolation. Many of exhibits were extremely sensitive and difficult to handle. But also small problems made the work more difficult: lighting conditions, lack of

stable power supply, lack of space for setting up the necessary equipment to mention a few.

- The project for digitizing musical instrument showed that still the work of a expert cretan lyra manufacturer can very difficult be copied and reproduced using the available 3D scanning and 3D printing techniques.
- Recreation of ancient skulls or bones with 3D printing proved to be very helpful to archeologists, who since now had tied hands in their research due to a strong possibility of damaging the real exhibit.

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# A MULTIMEDIA APPLICATION FOR EXPLOITATION AND VIRTUAL FRUITION OF ANCIENT ARCHAEOLOGICAL ARTIFACTS: THE EXPERIENCE OF THE 2<sup>ND</sup> CENTURY ROMAN BALTEUS OF AOSTA

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**KEY WORDS:** 3D Documentation, Digital models, Exploitation and Fruition, Museum Applications, Multimedia, Cultural Heritage

## ABSTRACT:

The need for a "space" both physical and digital, within which to burst a presentation as much complete as possible of an object of extreme importance from an historical, cultural, and archaeological point of view like the Balteus of Aosta, during its absence from the Archaeological Museum of Aosta, owing to a temporary exhibition, represents an occasion for experimentation at different levels.

A first level regards the methods followed to create the complete and reliable 3d digital model of this complex artifact: a new low cost technology, entirely based on digital scanning of high quality images through the application of stereo-photogrammetric principles, was tested. This new technology allows to obtain point clouds with RGB information and geometries at different levels of complexity, processing a number of images taken with a limited set of constraints (three shots for each station) and with the use of a special acquisition equipment through a sophisticated algorithm.

A second level regards the definition of an internet-based application to guide the visitors through a virtual exploration and fruition of this artifact, catching their attention and stimulating them in their curiosity and desire to know this object. Several 3d models of the Balteus, exported in VRML, were linked to a very articulated web site, designed to provide an exhaustive and interactive documentation system. Digital representation of the models is interactive, as users can navigate them and explore them easily by means of the web site interface.

## 1. INTRODUCTION

### 1.1 Preliminary remarks

Different new survey technologies play a leading role in the process of knowledge, documentation and exploitation of the architectural, cultural and environmental heritage. They allow us to acquire geometric data that can be used to define an exhaustive description of all the geometric features and peculiarities of ancient monuments or historical-artistic heritage.

Such a complete geometric description represents the first step for achieving an *integrated knowledge* of the artifact, that is first of all necessary to manage and program correct conservative interventions and restoration operations. Besides, digitalisation of acquired geometric data, thanks to appropriate software, allows us to make the same data available to different typologies of users in order to spread and share knowledge for cultural heritage exploitation.

For example, the reconstruction of photorealistic 3d models, useful to produce a global representation of the artifact, allows users to quickly understand its characteristics even if they are not experts (Martinelli, 2006).

In recent years many tools for 3d computer graphics have been applied to the field of cultural heritage: different types of visual outputs (wireframe models, neutral 3d models, photorealistic rendering) and different degrees of visual accuracy (high resolution 3d models, simplified 3d models, multiresolution 3d models) can be achieved according to research aims (Rossi, 1999).

Moreover, interactive computer graphics methods can be widely used for digital-reconstructed artifact exploration in virtual environments available through internet-based technologies to make all the heterogeneous data collected in the documentation and conservation process interactively available not only to specialists, but also to the general public (Gaiani, 2003).

This paper focuses on description of the multi-modal approach adopted for achieving a complete museum presentation of an ancient archaeological artifact, a Roman Balteus, preserved in the Regional Archaeological Museum of Aosta (MAR), within a joint research project carried out by CNR Institute for Technology Applied to Cultural Heritage (CNR-ITABC) and the Superintendence for Cultural and Environmental Heritage of the Valle d'Aosta.

Since the Balteus had to be moved away from the museum for a short period of time in order to be presented in a temporary exhibition\*, it was necessary to provide visitors with several enjoyable instruments to focus their attention on this artifact during its absence, and to help them in getting a deep knowledge of it. A 3d virtual digital model reconstruction of the Balteus was provided to offer a means of interactive exploration to the visitors, in a suitable internet-based application available at a museum multimedia information point, capable of disseminating all the fundamental historical-critical information too.

\* The temporary exhibition "Roma e i Barbari", 26 January 2008 – 20 July 2008, Palazzo Grassi, Venice, Italy.

## 1.2 The study case description

The 2<sup>nd</sup> century Roman Balteus of Aosta, is an ancient bronze horse pectoral, for parade or perhaps for award, with figure tracery representing a fight between Romans and Barbarians, recognizable from the typical clothing.

The fight scene, developed on a semicircular bronze belt\*, is based on Hellenistic schemas, going back to models from Traianus time; the composition consists of figures separated from the background, with deep shadows, and reveals the typical Aurelian taste for relief techniques (Figure 1).



Figure 1: The 2<sup>nd</sup> century Roman Balteus of Aosta

Eight groups of figures are still visible all around the pectoral, located on the front and on the right side; from the remains of pins visible on the rear of the belt, it is possible to count another seven groups of missing figures: six from the left side and one from the right side. At the end of both right and left side two regular asymmetrical holes are visible, probably used to hook the belt; six other regular holes are located on the entire surface. The presence of hooking holes probably is due to the fact that the belt was attached to some kind of support, thus it should be considered as a complement for a statue.

Another possible hypothesis about its meaning and usage, derives from the place of its finding. The belt was discovered at Aosta in 1953, during the excavation works that uncovered a large residential and commercial quarter of the ancient city, next to the Main Right Door, *Porta Principalis Dextera*, within the so called *Insula 59* (Excavation led by Carducci - Finocchi, 1953). In particular, *Insula 59* was a large and complex group of buildings made of four main distinct sets of houses; in one of these houses a Mitreum was also found, a typical religious place commonly related to lower classes. Carlo Carducci left some notes about the finding of Balteus, according to which the belt must have been abandoned probably in one of the many hollows of the house (Carducci, 1959; Carducci, 1960). According to Silvana Finocchi, more precisely, it must have been just thrown in the filling of one of the hollows of the Mitreum before it was restored during the second half of the 2<sup>nd</sup> century. So, the Balteus of Aosta could be an “ex-voto” (votive

offering), just like another belt found in the city of Brescia during the excavations of the *Capitolium*.

## 1.3 Guidelines

Because of the strict deadline for the temporary exhibition, the project aimed to achieve in a very short time a complete Balteus’ documentation, enough detailed in geometry and colour information to derive a photorealistic 3d model of the artifact to be placed in an interactive virtual museum representation.

The Balteus represents a challenging task for the 3d photorealistic modelling goal, given its complexity both from the geometric and colorimetric point of view: on the one hand the presence of different decorative figure in high-relief, characterized by areas with high surface curvature or part overlapped one upon the other, make particularly hard the complete reconstruction of its shape and physical features; on the other hand the bronze component material, characterized by a dusky metal patina with copper outcrops, leads to high reflective surfaces, not easily documentable in an homogenous way by a multi-view image sequence necessary for realizing the complete 3d model texture.

Another important project goal was to keep low the global cost of the artifact documentation and exploitation. The frequent economic inadequacies of the authorities engaged in preservation of Cultural Heritage, lead to the necessity of using the most part of financial resources to solve conservation problems or to face urgent restoration operations, leaving out exploitation and fruition aspects. Whereas the utilization of low cost technologies to document and communicate about Cultural Heritage would allow also small Public Administrations or local museums to emphasize and to bring their natural and cultural heritage to light.

All these aspects led to three essential choices:

1. the decision to adopt, for the 3d Balteus’ survey, a low cost technology able to guarantee that the two main aspects of spatial, visual and textural description would be achieved by one single type of equipment with the same precision, with the best optimization of acquisition and processing time;
2. the decision to use common web-based technologies integrated with modern open source tools for interactive visualization of 3d VRML (Virtual Reality Modelling Language) models, to set up a suitable interactive environment for performing the Balteus’ museum presentation and to reduce IT programming working time;
3. planning of the work according to precise technical and organizational criteria, in order to allow the different operators (architects, information scientist, etc.) to simultaneously work without useless time lines.

As far as point n. 1 is concerned, we decided to use an innovative comparatively low cost technology entirely based on digital scanning of high quality images through the application of stereo-photogrammetric principles, even in an experimental environment; it represents a close range sensor that allows images capture and RGB point clouds extraction from images pixels, thanks to a sophisticated algorithm for image processing and feature matching.

\* The belt presents a lower maximum diameter of 43 cm, an higher maximum diameter of 32 cm, a width of 10.8/18 cm, and at last an height of 20.7 cm.

This technology appears to be able to optimize acquisition time (since it allows to acquire simultaneously a spatial and a visual geometric proprieties of the object) and at the same time to guarantee a reliable result, with millimetric accuracy; so we preferred this survey technology rather than other range-based techniques, even more expensive, like laser scanning, that would not be probably able to solve all the problems related to the survey of the Balteus' surfaces complexity and physical features. Moreover, to acquire detailed surface colour information, laser scanning has to be supported by a photographic survey\*, with consequent additional hardware cost and post-processing work to integrate the different kind of data acquired.

In the next paragraphs we will outline the technological challenges, the logistical aspects and the possible project results.

## 2. METHODOLOGY AND TECHNIQUES USED

### 2.1 Technology description

The project represented a good opportunity to experiment an innovative instrumental survey system: ZScan\*\*, a low cost close range sensor, that allows the digital scanning of multi-view high quality images sequences, through the application of a sophisticated algorithm for image processing based on stereophotogrammetric principles. This new technology can be used to obtain RGB point clouds and geometries at different levels of complexity, starting from the treatment of a number of images, taken with a limited set of constraints and with the use of calibrated digital camera and a special acquisition equipment.

The acquisition equipment consists of a calibrated aluminium bar, which can be easily mounted on a photographic tripod, and which is provided with a small trolley for supporting the digital camera (Figure 2). The trolley allows to move and to secure the



Figure 2: The ZScan survey systems (Menci Software)

\* New type of laser scanner are nowadays provided with an high-resolution calibrated digital camera so as to simultaneously acquire x-y-z spatial coordinates and RGB value of every single points. However the price of this high quality range-sensors is often very expensive, not easily sustainable in the greater part of Superintendence's survey and conservation projects.

\*\* ZScan survey systems, manufactured by Menci Software of Arezzo.

camera in different known positions, represented by several holes at fixed and equidistant intervals on the bar, in order to allow sequences of images of the same object from different angle-shot.

To produce a single point cloud, a sequence of three images, has to be taken from the left to the right, shifting the camera along the bar. The left and the right shots must be symmetric compared to the middle of the bar, and the distance between them (the baseline) has to be carefully evaluated in relation to the optimal distance of the camera from the object, survey accuracy and level of detail needed.

For a complete image coverage of the object, several sequences of three images have to be taken, changing many times the bar position all around it. Both the bar and the digital camera have to be calibrated; calibration of the optics employed is necessary in order to know the distortions due to the lenses within the objective and to send calibration parameters to the software for data processing. The instrumental survey system is indeed endowed of a dedicated software, necessary for the creation of the single point cloud from each sequence of three images acquired with the bar. Another specific software can be used then to connect all the single scans in order to obtain the overall point cloud of the surveyed object\*\*\* ("point cloud registration").

The systems satisfies characteristics of great flexibility and ease of use and guarantees, at the same time, accuracy of the geometric data acquired. Moreover it should not require the use of topographical support point, in order to create the single point cloud\*\*\*\*.

However, the system uses an image processing algorithm for 3d reconstruction that has some limits of application in relation to the characteristics of measured object surfaces. It reveals limits processing 3d point cloud reconstruction of surfaces endowed with homogeneous colours, repetitive patterns or high reflective materials.

## 3. 3D ARTIFACT DOCUMENTATION

### 3.1 Data acquisition

To achieve the complete photographic coverage of the Balteus, through the use of ZScan survey system, the planning of all the different instruments positions were carefully discussed, in order to acquire the most part of the undercuts or covered parts of the decorative figures. The Balteus is substantially a semicircular bronze belt with moulded borders and two triangular extensions in the central section both ending with a truncated conical vertex. So we decided to ideally subdivide the semicircular surface into different portions, that could be easily acquired orienting the bar position, step by step, all around the artifact.

\*\*\* Zmap Laser software produced by Menci Software of Arezzo. It is a program for processing point clouds obtained from either digital scanning or laser scanning. It generates high quality orthophotos for cartography, compiled 3d streaming models, and vectorial restitution.

\*\*\*\* The processing software allows anyhow to insert and collimate specific control points (*ground control points*), in order to georeferencing the single point cloud, in relation to a global datum system.

Each portion of surface was photographically acquired with three images shifting camera position along the bar; we adopted an overlap between two subsequent portion of surface acquired of about 30% in order to allow the global registration of the single point cloud obtained. Moreover, for each portion of the semicircular surface, we repeated the photographic acquisition adopting three different angle of inclination for the camera: with a vision axis perfectly orthogonal to the surface; with a vision axis inclined towards the top; with a vision axis inclined towards the bottom. In the case of the photographs acquired with an inclined vision axis, we decided to take a rotation angle, with respect to the vertical, of no more than 15°, in order to minimize photographic deformations. These kind of shots were however essential to reduce the number of hidden parts of the decorative figures, in consideration of the complexity of this kind of historical-artistic artifact with many occlusion areas.

The same procedure was adopted for acquiring the internal part of the belt. The possibility of link together the internal and the external Balteus' semicircular surfaces was guaranteed by specific angle shots that included both these physical parts of the artifact. Finally, due to the complexity of the surface, more than 600 high resolution pictures were taken, in one an half days of work, with a Nikon D-200 digital camera (CCD sensor of 10.2 megapixel, 35mm and 24mm lens used) calibrated in a certified laboratory UNI-Normal.

In order to obtain a great survey precision and an high representation detail, the shots were taken with a camera distance of only 70 cm from the artifact, with a subsequent baseline of 10 cm\*.

We decided to acquire image sequences in homogeneous lighting conditions to optimize the quality of the overall models and, above all, to avoid big light changes in intensity and direction between a shot and others along the same bar position. Different tries were made: a first series of pictures were taken outdoors with ambient light, in a cloudy day, using a 35 mm fixed optics; a second series were acquired indoors, using a 24 mm fixed optics and paying special attention to artificial environment lighting conditions. All museum halogen lamps facing the artifact were turned off, in order to avoid any possible specular reflection due to the high reflective bronze surface of Balteus. Moreover, a special set of two professional diffused lights were employed for eliminating all shadows created by the complex surface of the artifact as much as possible, in order to prevent any loss of data, and to avoid excessive colorimetric differences between one sequence of images and the other.

Unfortunately, notwithstanding these lighting expedients, the final triplet sequence of images produced still showed a prominent radiometric difference of RGB colour information; this means that the 3d final model texture, being composed of multiple images, cannot be completely homogenous in the colour information.

### 3.2 Data processing

The first processing step, after gathering all the data acquired, was the chromatic correction of the images through the use of image processing commercial software (Photoshop); we tried to achieve a better chromatic equalization between different shots, carefully applying the same colour balance to all the three

images that form any single image sequence, acquired from a specific position of the bar. After some test executions we decided to use the photos acquired indoors to create the final 3d model of the Balteus.

The processing of every single triple sequence of images, finalized to extract from each of them a specific RGB point cloud, was then performed through a dedicated software that is part of the ZScan instrumental survey system. This software allows to rapidly load, without any preparatory phase, the three images of each scan position and the relevant acquisition parameters: the baseline adopted and the calibration file of the lens used (Figure 3).

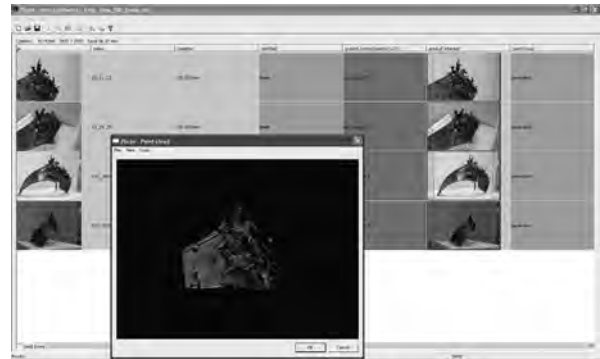


Figure 3: Creation of RGB point cloud from data processing of each triple sequences of images

The subsequent procedure for RGB point clouds extraction, consists of four main steps: images rectification, through the application of trinocular rectification and feature matching, in order to eliminate geometrical and optical distortion; selection of the image areas of interest (AOI) that have to be processed; definition of the step resolution value, measured in pixel unit; production of a point cloud relevant to each group of three images, through the application a sophisticated algorithm for image processing.

The point cloud contains both spatial and colour information, xyz co-ordinates and RGB values for colour rendering; moreover, in order to display a texture representation on point cloud, it is also possible to create a mesh of every single point cloud, thanks to a triangulation process, once that the maximal distance between two points is defined. The point clouds are automatically converted into surfaces, performing a triangulation process similar to the terrain modelling case, i.e. in relation to a main view reference plane. The 3d surfaces obtained are therefore completely visible only when the viewing angle is close to the one adopted in the acquisition phase.

According to the extreme artifact complexity and to the homogeneity of component material, a step resolution value of 1 pixel was adopted, corresponding to 0.13 mm point to point sample spacing on the created point cloud. Such a detailed elaboration, probably even too much excessive in relation to the detail needed, was considered necessary for helping the subsequent registration of the single point clouds, performed through the collimation of homologues significant natural points, since it wasn't possible to apply any kind of artificial targets on the artifact surface.

At the end of this first part of data processing we achieved several high quality RGB point clouds, within millimetric accuracy, and then detailed photo-realistic 3d models of single

\* These configuration allows to achieve a theoretical depth accuracy of approximately 0.5 mm.



Figure 4: Example of high quality RGB points and photo-realistic 3d models of a portion of the ancient artifact

different artifact portions (about 36 different models): some of them were used in the museum presentation, to allow visitors to deeply analyze details and specific features of the artifact (Figure 4).

Different attempts were made to achieve a general 3d representation of Balteus, to give museum visitors an idea of the uniqueness of this historical-artistic artifact.

We first of all proceeded with the global alignment of all the single models obtained from every triple sequence of images. Registration was performed in Zmap Laser software, checking errors propagation during all the orientation process (Figure 5). In fact, the software allows to perform two typologies of registration process: a first semi-automatic registration, achieved through the operator recognition and collimation of homologues significant control points between two different point clouds; a second automatic registration, performed using an ICP algorithm, for refining the first alignment. These procedures were both used, for each overlapping pairs, in order to minimize alignment errors.



Figure 5: Registration of two different point clouds using Z-Map Laser Software

The final merging process was performed through the use of another standard software for scanner laser data 3d modelling, Rapidform by INUS Technology Inc. The global model obtained wasn't, however, completely satisfactory and presented too many holes and discontinuities on the surface; the strategies of merging together different surfaces, each one triangulated in relation to a main view reference plane, could

lead to neglect some important geometric information, obtainable only considering together all the different point cloud acquired from the different instrument points of view. The surfaces triangulation processes was then repeated with Rapidform software utilities.



Figure 6: Final photo-realistic global model of the Balteus

All the different RGB point clouds were imported and merged together, after cleaning all the non relevant parts, in order to eliminate overlapping data. We achieved a global point cloud of about 12 million of points, that had to be decimated down to 4 million of points, before performing surface mesh generation, in order to avoid elaboration software failures, due to computer physical limits of RAM memory. The final model, was more complete than the first one, but still presented several data holes and surface discontinuities; the most part of them were interactively filled through the use of specific surfaces editing functions, however, because of the artifact complexity, some inner concave parts and occlusion areas still remained undocumented also in the final model (Figure 6).

For these reasons and considerations, this survey should be considered as a working in progress result, derived from the experimentation of "limit conditions" of ZScan technology used, in consideration of the complex physical characteristic of the artifact, in terms of morphology and colour features. The complexity of the decorative figure in high-relief, that overlapped one upon the other creating visual occlusion, and the high reflective bronze material stretch the image processing algorithm used to the extreme limits.

#### 4. THE WEB-BASED APPLICATION INTERFACE

##### 4.1 The presentation structure

The creation of an interactive environment where to perform the Balteus' museum presentation started at the same time of 3d data processing for geometry reconstruction of the artifact. During Balteus' absence from the MAR of Aosta, an enjoyable internet-based application, accessible from a specific museum multimedia information point positioned near its temporarily empty showcase, was provided to allow the museum visitors to imagine it and to get an overview of its historical-critical peculiarities.

The problem of presentation of this research and all the necessary background information that the visitors need in order to have a reasonable vision of both the artifact history and the technological scene behind data processing, was solved



by means of a web site. As MS Internet Explorer™ is the most popular web browser at the moment, we decided to adopt it as a default browser to operate the presentation in order to rely on visitors confidence and knowledge of it. Besides, the PC selected to host the presentation, was provided with a touch screen for immediate and ease of use.

The application was designed to be interactive and to become a tool to organize, represent and disseminate all the *knowledge* related to this archaeological artifact. In order to give as more complete as possible description of the Roman artifact, useful to describe all its features and characteristics, a large amount of heterogeneous data were therefore handled, organized and collected: geometrical representation, text descriptions, graphics data, raster images, multimedia contents, animations, anaglyphics, 3d VRML models, and even sounds.

The completeness of the information was pursued: from the homepage of the multimedia application, simply clicking on specific icons, it's in fact possible to approach all the contents of different informative levels, through the use of link-based connection.

A first level regards the *physical knowledge* of the artifact: the users can look through a picture gallery of all the artifact images acquired during the survey activities (indoor and outdoor photos, 35 and 24 mm lens used photos). Moreover he can understand the complexity of its configuration, thanks to the possibility of an interactive three-dimensional navigation of its global simplified digital model, or he can appreciate its decorative figures and its workmanship peculiarities, through the visualization of the high level of detailed 3d models of single portions, even in anaglyphic way (Figure 7).



Figure 7: The web-based application interface: anaglyphic visualization of a detailed 3d model of the Balteus

The 3d model interactive exploration is made possible through the use of an open source tools for 3d VRML model visualization, Cortona VRML Client of Parallel Graphics, that endows a web-based application with all the functions of a VRML browser. Interactive navigation of the artifact is achieved with the control of the mouse and simple keyboard commands: the viewer can pick the artifact up, freely rotate and examine it.

A second informative level regards the *archaeological and historical knowledge* of the artifact: the museum visitor can have an idea of the main historical-critical investigations relevant to the Balteus. In particular he can analyze texts and images relevant to the archaeological excavations that led to its discovery and relevant to its physical and decorative characteristics and those of other similar finds discovered all over Italian land (Figure 8).

A third informative level regards the *research activities results knowledge*: the users can get an overview of the methodologies adopted during data acquisition and processing for achieving the Balteus' survey and 3d model reconstruction.



Figure 8: The web-based application interface: historical-critical comparison between Balteus and other similar finds

The dissemination and transferability, also to the general public, of the main results of innovative researches relevant to Cultural Heritage conservation, management and exploitation, is of particular value to the goals of sharing knowledge. To this end several diagrams, animations, texts and images call users attention to the main phases of research activity, explaining them in the as much simplified and immediate way as possible.

The last informative level regards the *belongs cultural territory knowledge*, thanks to the possibility of suggesting a connection between the object and the background, the culture and the history, and a reverse connection between the background, culture and history to the single object itself. We try to develop the theme through a multidisciplinary approach, looking at the rich history of the territory from which Balteus originates. To this purpose we decided not only to insert several texts and images relevant to the ancient Augusta Praetoria history, characteristics and remains, but also to connect different logical and semantical links together. In particular we suggest a correlation between the Balteus itself and other important historical remains of the city of Aosta, the Triumphal Arch of Augustus, built to represent the same victory of the Romans against their enemies. This is achieved inserting the possibility of examine interactively also to the 3d VRML digital monument of the Arch already, created within another research project developed with the Superintendence for Cultural and Environmental Heritage of the Valle d'Aosta\*.

\* This last project carried out by the CNR Institute for Technology Applied to Cultural Heritage and the Superintendence for Cultural and Environmental Heritage of the

The web site was thus organized in four main sections plus a help page. The first section concerns the general presentation of the manufacture and all the techniques used to acquire and process data from scratch through the end. This section also presents samples of the same techniques applied to objects at different scales, like Augustus Arch and a medieval capital. The second is an exhaustive presentation of the manufacture and its archaeological backgrounds, from the urban area where it was discovered through a comparison with other similar findings from all over the nation. The third section is about the research group itself, the people and their activities, and finally the last one is a complete reference section.

## 5. CONCLUSIONS

The work was a valid occasion to experiment the application of a low cost innovative survey system, based on image capture and processing, for digitization and 3d model reconstruction of an ancient archaeological artifact.

The technology used gave satisfactory results in terms of surveyed number of points and precision in the location of the acquired surfaces, even produced by different instrument positions. Moreover it allowed us to achieve at the same time a geometric and color documentation (point clouds with RGB color information) - paramount to produce photo-realistic 3d models in which morphological details, components materials and colorimetric definitions can be easily showed.

The results of the 3d model processing come up to the system specifications and project requirements, although the final global model still presents several data holes and surface discontinuities, due to the extreme complexity of artifact morphology, rich of recesses, cavities and partially occluded and reflecting surfaces, that would probably be an issue and a difficult challenge for every other range-based survey technologies.

The several photo-realistic 3d models of the Balteus available during its absence in a specific internet-based application for museum exhibition positioned in the MAR of Aosta, could guide the visitors into a virtual exploration and fruition of this archaeological artifact, allowing them to get a deep knowledge of it even without the possibility of a real vision. It would be desirable to preserve this multimedia interactive application even after the Balteus comes back from the temporary exhibition, to provide the visitors with a deeper and wider knowledge of it. In fact, interactive 3d digital models can focus visitors attention on the artifact, and allow them to make the visit a different experience: they can look at the artifact from any point of view, even from unusual directions; moreover they can change artifact lighting conditions, to examine any kind of physical and material peculiarities.

But it is important to remember that the use of these computer tools, specific to ICT for the valorization of Cultural Heritage, have to be considered only as an optional implement for

stimulating the real knowledge of an historical-artistic artifact. In fact, they could never substitute the visual and emotional experience, attainable only through a real walking around this unique and unrepeatable objects.

At last we would like to underline the importance of museum exhibition internet-based application for the management of all the historical-critical information about an artifact and for their transferability also to non expert users. The dissemination and sharing of the main results of scientific researches (geometric and architectural survey, historical-critical investigations, decay and instrumental analysis, etc.), in a more or less simplified way according to the different kind of users, could help to make the different Cultural Heritage conservation and valorization strategies, diffusely supported even by common citizens.

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Valle d'Aosta aimed to achieve a precise scientific geometric documentation of the Triumphal Arch necessary to help the process of decay condition and possible static damages diagnosis, and to precisely refer to the monument geometry all the data acquired during the monitoring activities and the analyses relevant to materials alteration and decay (Salonia et al., 2007).

## MULTIMEDIA FOR LEARNING ABOUT PRE-COLUMBIAN WEAVINGS IN A RECREATIONAL ENVIRONMENT

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**KEY WORDS:** Software Usability, Games Multimedia, Heritage Culture, Andean Weavings, Education.

### ABSTRACT:

This work presents a multimedia environment of entertaining information and puzzle games of pre-Columbian weavings, as part of the educational activity of the Azapa Archaeological Museum of Tarapaca University, San Miguel de Azapa, Arica-Chile. The purpose is to stimulate the creative part of the students and open informative and funny complementary to the studies in subjects such as history, art, design, and pre-Hispanic technology. The philosophy is to learn playing in a educational environment, for this, there is an Andean Loom in 3D, that allows to play with the creation of weavings from the pre-Hispanic world, also a set of 2D puzzles are provided, which allow interact in a funnier and more didactic way with the archaeological object, encouraging the skill of seeing the intricate pre-columbian signs and symbols that most of the time are unprovided because they are not part of the modern student's ideology.

The software was evaluated with primary and secondary students from schools of Arica. This educational instrument was implemented with Flash multimedia, Visual C++ and graphic libraries compatibles with OpenGL.

### 1. INTRODUCTION

The archaeologists have denominated as Arica Culture to the societies that lived in the valleys and coast of Arica–Chile from the year 1.000 to 1.470 A.C., that is to say between the decadence of Tiwanaku State and the expansion of the Inca State from Cuzco. Arica Culture includes the most relevant political, social, economic and symbolic development of the pre-Hispanic history that allows explaining a big part of the singularities of the region Arica and Parinacota Chile (Carmona et al., 2004).

The regional textile art was characterized for the inclusion of iconography and designs, using forms and colors that expressed the cosmology of the Andean man in that period. These features gradually disappeared during the Inca dominium and were left behind during the Spanish colonial period. In spite of everything, some ornamental tendencies still survive thanks to our handicraft people. They print in their weavings the old view of the world and identity values without knowing their ancient meanings. The Andean weavings (Ulloa et al., 2000) and their antiquity proved by science, contain a wealth of ideas, whose interpretation does not go hand in hand with the importance of the contribution to science and national culture and universal culture, because of that it is necessary to develop methodologies that stimulate the knowledge of a world that has always been present. The construction of an educational environment using graphic computer science and multimedia technique, allows to develop a virtual platform for the approaching to archaeological pieces that are not easy to handle and, stimulate its perception and interpretation in a more interactive and attractive way (Córdova-González, 2007).

The main idea is to develop an entertaining virtual environment that allows integrate a pre-Columbian weavings learning in the

Archaeological Museum San Miguel de Azapa\*. The indigenes' typical clothes will be presented in this virtual environment, with different forms for different ceremonial activities or daily activities. In this way, the users will be allowed to interact with the weavings in a more didactic and entertaining way, in order to demonstrate that the environment allows stimulating the creation learning and playing at the same time, such as in the work of Wiberg et al., 2003, that shows the satisfaction of learning through games.

To get the indicated goal, an entertaining learning, a virtual environment of Puzzles in 2D was developed, with three levels of complexity, one for smaller students of six pieces, another for intermediate with sixteen pieces and the last one more difficult of thirty six pieces. Besides, a sample of Andean weavings, that we called Loom 3D; the software user that is able to see signs can transform them into symbols, helped by the visual and intuitive content, in that way the user is primary interpreter of this textile work. Digital and educational environment about prehispanic textiles have been no reported yet, that is why the relevance of this proposal is considered which respond to the existent needs, inviting the visitors of the museum to have an active role, as protagonist of their own learning process and not joined to the traditional models in which only the given materials satisfy their knowledge. From this idea, the visitor must build their own meanings.

The virtual environment was evaluated using a group of primary and secondary students from schools of Arica, the objective was to verify the usability of software and its capacity of getting the cognitive objectives that motivated the project.

The following is the presentation of a set of related works, the modeling of the architecture of this educational tool, the

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\* San Miguel de Azapa Archaeological Museum Tarapaca University, located in Azapa Valley kilometers 12, Arica city, in the northeast part of Chile

respective tests of the learning process involving the results of the software of the indicated sample. The described evaluation in this paper is experimental, with the objective of conducting the use and personal satisfaction towards a more entertaining learning.

## 2. RELATED WORKS

### 2.1 Learning in museums

In museums around the world there are many works performed considering virtual environments, with several objectives. The set and the reach of these educational and cultural games vary in a considerable way. An example of this is the interactive map of the sites and monuments of the Kilmartin House Museum valley in Scotland, about interactive monuments and 3D games worked by Winterbottom et al., 2006. Another complex project is the trip on line of the caves and the archaeological site of Qumran, Virtual Qumran (VQ) of San Diego Natural History Museum (Schriedewind, 2007). Also the games known as Prismaker, these allow to differentiate in an educational way the comparison of the learning by a virtual game versus a real game, like the job performed by Lopez et al., 2000 or Montero et al., 2001 and Ruiz et al., 2002, showing virtual environment that allow observe the educational capacities that present the virtual games opposite real games. Some of these virtual games help to understand a culture, as we can see in the work of Ruiz et al., 2002, that shows the Maya culture through the virtual reality.

In Arica-Chile, the Archaeological Museum of the Tarapaca University disposes a catalogue of digital collections, exhibitions on line and the educational site software Yatiqasiña (Cordova-Gonzalez et al., 1999) that centers the user's interest in the Chinchorro culture. Yatiqasiña disposes of different environments of work: motivational, providing information in a wide set of topics related to the cultural period; of games, including different skills; of construction of knowledge with an investigation platform and, an environment of literature creation with the possibility of writing a story about the Chinchorro culture and the visit to the museum in 2D (Ramirez et al., 1998).

### 2.2 Learning through games

The computer games are more popular each day in education. Studies such as in Marçal et al., 2005, Barbieri et al., 2001, Maria et al., 2004, López et al., 2000, González et al., 2001 and Montero et al., 2000, indicate that children and young people stay long periods of their lives entailed to virtual entertaining, as a consequence of that it is necessary to provide contents related to this kind of platform, for the same reason, most of the information in museums could have a better use in a more attractive way and also with big graphic contributions that allow to continue playing.

It is significant to notice that the creation of virtual environment through the incorporated games in the educational contour, have a clear function in developing cognitive, social and resolute skills, so we can conclude that games as main activities for children, allow to develop aspects like; analysis and synthesis, imagination and formulation, it has been proved that a child progresses through ludic activities. Several of these contributions were acquired because of the attractive in digital games, 3D worlds and visual interfaces that encourage children and young people.

### 2.3 Evaluation of the Learning through games

In general, teachers that take their students to learn in a museum consider that is not possible that their students can learn, they understand that museums provide or facilitate information that can be used for the school system, but during the visit the learning is not acquired. So in the local contour, the investigation of Andean weavings has an experimental value whose purpose is to facilitate the perception of communicative and relation values through a digital technology taking a sample Pre-columbian weaving that belongs to San Miguel de Azapa Archaeological Museum. For this purpose, it will be necessary to design and produce an educational environment that facilitates information about the interpretations of the weavings done by anthropologists, archaeologists and specialists in museums, this will allow the user to fix the attention in signs and symbols, and inquire about other forms of communication not previously integrated. Today, we consider that visitors from San Miguel de Azapa Archaeological Museum build a subjective point of view about the cultural contents presented in the exhibitions. We aim to encourage them to do a creative observation through a technological support using a game application. To verify this hypothesis, we will choose from the museum collection a sample of Pre-columbian weavings which are considered as aesthetic expressions instead of cultural content manifestations (Cordova-Gonzalez et al., 2007).

Then the idea is to build a virtual environment of funny learning, through the applications that allow the person to interact with the prehispanic weavings, exposed in the San Miguel de Azapa Museum.

### 2.4 Usability of educational games

The usability is very important in the educational games, because they let establish the success of the software evaluation result. Considering the user, in the components some attributes such as the easy learning, few mistakes and user's satisfactions are traditionally associated (Sanchez, 2000). This concept can be measured and for that we can use a set of methods that allow identify the way in which the users interact with a prototype or with a complete site. Besides from the software engineering, in the case of educational games there are several aspects that must be considered, such as the complexity of the interface of a game, the entertainment, the narrative, the context, etc. Another important point could be the educational environment in which the game is involved, that is to say, the learning environment will be composed by goals and missions that the player will have to get during the game (Yacci et al., 2004).

The usability and the fascination for playing, in the case of software VR-ENGAGE demonstrated by Virvou et al., 2008, revealed an improvement in the learning of students of different categories. For the analysis of each test, the students were classified in three groups; beginners, intermediate and experts. These considered some characteristics of the user interface, effort and distractive elements.

This analysis concluded that the educational applications could be more motivating and equally attractive for the students not only at school but also at home.

### 3. ARCHITECTURE OF EDUCATIONAL SOFTWARE

#### 3.1 Interfaces

**3.1.1 Puzzle Game:** Each puzzle has a simple interface using just the mouse to make it work. Talking about interaction that games have, we can say that these follow a very clear logic that is to capture the interest of the user through simple steps, like a simple bottom that spread information or a “click” in another bottom that executes a determined action. The Simplicity of these games involves a quick comprehension of the tool that produces a deeper knowledge of what we really want to show in these games.

This implementation considers this aspect, to induce an efficient and quick learning for children, young people and adults about virtual educational games.

The virtual environment implementation of the puzzle: Using pictures of three pre-Columbian weavings exhibited in the Exhibition room of the San Miguel de Azapa Museum called Chuspa\* (Figure 1), Tari\*\* and Bolsa-Faja\*\*\*, puzzles were performed in three different levels for each weaving image.

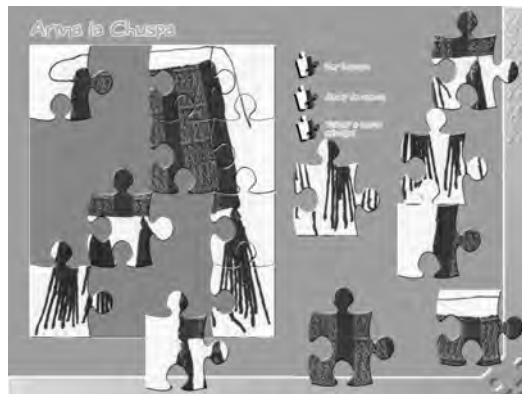


Figure 1: Starting a puzzle game Chuspa

In the first place the images were cut in aleatory way, the form must be special in order to assemble the pieces and set all the functions in Flash. As in all the puzzles, the idea is to carry the piece to a section in which all the pieces can be joined, in order to form the complete image.

As a help the user has the option of visualizing the weaving that he is going to form. The user has the possibility to form five puzzles from a menu (Figure 2) two of six pieces, two of sixteen pieces and one of thirty six pieces.



Figure 2: Main Menu to choice puzzle

As important part of the design, this presents several options (Figure 3) which would indicate the option to listen to music, if the user wants to listen to Andean music while he is playing, the help, video and animation, and the last option is exit the game.



Figure 3: Options main environment of puzzle

The “help” icon (Figure 3) presents an animated video that shows step by step the construction of a puzzle, indicating the instruction in a written and auditive way. (Figure 4)



Figure 4: Help Video

Each puzzle will have three options: “See image”, “Play again” and “Back to main menu” (Figure 5).



Figure 5: Options to play any puzzle

\* Bag elaborated to carry coca leaves.  
 \*\* Small tablecloth to put some presents on the ceremony table.  
 \*\*\* Long bag, used to adjust the shirt, ornament and transport of valious objects.

The last step was incorporate voice to the main menu of software (Figure 2), the purpose is to give the user the possibility of reading and listening a brief description of the weaving. This is a great help for small children that are not able to read yet and people that have difficult to read.

Educational Contents of the Puzzles: When you pass the pointer of the mouse by the name of any weaving in the Menu it is possible to hear the name and a brief description of the weaving is shown, Tari, Chuspa, Bolsa-Faja (Figure 6) and a descriptive image is associated to the text. This allows to know different textile forms, their uses, their meanings as clothes that are not always functional.



Figure 6: Description of the Bolsa-Faja weavings, previously selected in the Main Menu

All the puzzles have a simple functioning, which consist on forming an image of a weaving according to the number of pieces that they have.

To play with this simple application known in the whole world, provides the opportunity of watching the final image shown by the application, the importance is that each image shows a unique history. Besides, we must consider that this funny virtual environment, give us the opportunity of watching inedit images of pre-Columbian weaving, which we can only see in the Azapa Archaeological Museum, Arica Chile.

**3.1.2 The Loom 3D:** A different way to pass the content, was to present the icon of weavings, called Loom 3D, to show in a static (text and image gallery) and dynamic way, how to build a piece of Andean weavings selected by the users. This integration will give the user the possibility of getting information, in a more entertaining way, because the user will have to build information through the interaction, getting involve with the virtual model of the application, forming in this way, his or her own intuitive idea of the fascinating world around him/her.

The Virtual implementation of the Loom: The main window of the application shows a visual interface divided in three sections, the interaction window with the Loom 3D, the toolbar and the image gallery with a descriptive text, as shown in figure 7.

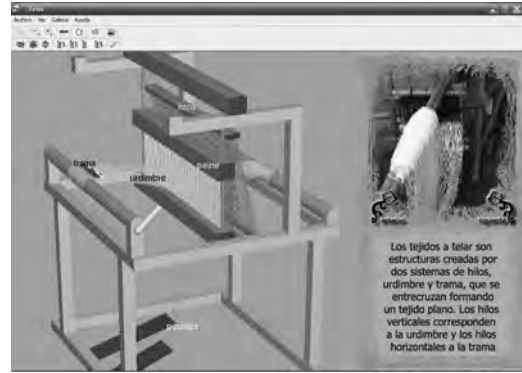


Figure 7: Main menu, which initially introduce the structure of the Loom along with a description respectively

The tools bars (Figure 8) illustrated all the tools of application, indicated by an icon relative to the action to do, these are rotating (allows rotating Loom’s structure to be observed by different angles), zoom, speed (speed of the knitting process), restart (returning to the main menu), pattern image (allows seeing the image and the text of the pattern respective to the weaving) and other image gallery.



Figure 8: Toolbar for the main menu

The work bar (figure 9) illustrate all the options of the process of weaving, these are pattern (selection of the knitting pattern, llama, frog or lines), colors (selection of each color palette for the three or four color threads, according to the used pattern) and rolling (at the end knitting process, you can see the rolling process by clicking this option).



Figure 9: Work bar for the main menu of the Loom

Educational Contents of the Loom: At the right of the application, you can see the image corresponding to the pattern or the image gallery, which is related to an informative text of the respective image, as the illustration of the figure 10, to change the image it is necessary to click on “anterior” or “siguiente” buttons.



Figure 10: Image and text real associative of a Loom Andean

The interaction of the Loom, consist on selecting a pattern established in the work bar, then to the weaving segment , the user must click on the selected pattern till finish the process of weaving, in that way the user will have the possibility to observe the advance of the weaving, as it is shown in figure 11. This process can be seen from different angles through the rotate icon of the toolbar, then, once the icon is selected, the mouse pointer will transform it into two circles, indicating that it is possible to rotate the Loom from other angle, holding “click” and taking it to the desired position. In this process, the user can see images from the gallery or read texts of each image of the pattern at the same time. Once weaving is done, the user will be able to roll it for the observation of the Loom functioning. Besides, the user will have the possibility of testing any pattern of the application, proving that the process of weaving is basically the same.



Figure 11: A screenshot of application in the process of weaving, in the case of a frog pattern

### 3.2 Modelling

**3.2.1 Puzzle Game:** This model performs a life cycle that corresponds to a process of the construction of this virtual game. It is based on a model of process of the usability engineering (Lorés et al., 2003 and Pressman, 2005).

Application requirements: The user has access to the main menu that will be given at the beginning of the game. The environment has five different levels games, background music and a help video.

Game Interaction requirements: When the mouse pointer is on a weaving name, the game will give written and auditive information about the weaving description. Each puzzle has three bottoms, view Image (on mouse over, it will be shown briefly the image as help), play again and go back to menu. The help video indicates in a written and auditive way how to assemble a puzzle. It has function bottoms similar to those in a video player.

Non functioning requirements: The game can be operated with a window environment or in an alternative way it can be visualized on the web that provides Flash player, supported in every operative system and any person that set the game can have access to it.

Design Game: The entity-relationship model (ERM) is an abstract conceptual model representation of puzzle game (figure 12).

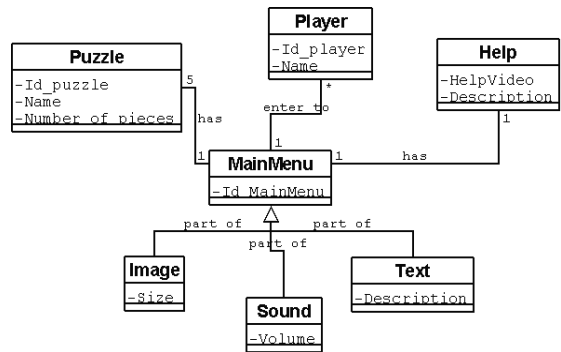


Figure 12: Conceptual Model of puzzle

**3.2.2 The Loom 3D:** The same engineer process was considered for the Loom modelling, but programming languages and graphic interface were included.

Application requirements: The user has an access interface through the illustrated iconography in each bottom. The application has a toolbar and a work bar, the environment has 3D access for the animation and 2D access to the image gallery and respective text, it has three kinds of weavings, considered patterns to perform the activity of virtual weaving and the application has a help file.

Requirements of the users’ interaction with the application: The user can weave in the Loom by “clicking” on the selected pattern, having access to the information and images gallery respective to the pattern. The tool bar provides different activities, enabling 3D rotation, change weaving speed, modify zoom, reinitiate application and access to images gallery. The work bar provides different activities, and patterns. Choose any of the three patterns, colour and bottoms to change the colour of the pattern thread and roll the weaving. The provided help from text and images, for a better comprehension of the application functioning.

Design Game: The entity-relationship model (ERM) is an abstract conceptual model representation of the Loom 3D (figure 13).

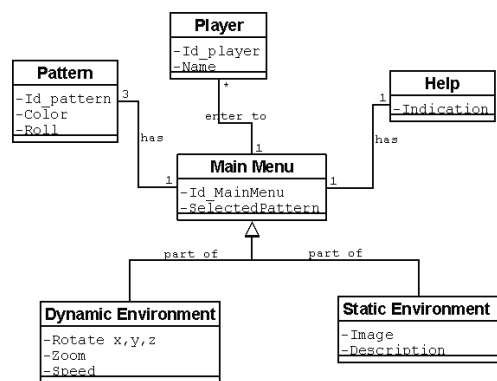


Figure 13: Conceptual Model of Loom 3D

#### 4. TEST

To do the tests that correspond to games was necessary to evaluate in software two groups of different levels of cognitive development: children and teenagers, in a continuous process, before and after the experience, following a learning process since the student arrives the classroom till the process is over, directed by the teacher of one of the subjects according to the topic that is pre-Hispanic history of the country.

##### 4.1 Participants

The number of students in the evaluating sample group was eighty three. The first fifty were from the "Colegio Integrado Eduardo Frei M." 20 of them were from the 4<sup>th</sup> grade "A", 15 from the 5<sup>th</sup> grade "B" and 15 from the 9<sup>th</sup> grade "A". The other selected students were from the "Colegio America", 15 of them were from the 4<sup>th</sup> grade and 18 from the 5<sup>th</sup> grade. The average age of the 4<sup>th</sup> grade students is 9 years old, the average age of the 5<sup>th</sup> students is 10 years old and the students of 9<sup>th</sup> grade have an average age of 14 years old, as it is shown in the table 1. They had to use the game and answer a brief survey with questions about the usability of the game, their opinions about their interests and the acquired learning.

Level / Age (years)	9	10	14	Total
Primary School	50	18		68
Secondary School			15	15
<b>Total N°Students</b>	<b>50</b>	<b>18</b>	<b>15</b>	<b>83</b>

Table 1. Summary Educational Level v/s Age

**4.1.1 Primary School Groups:** The primary students presented a similar pattern, which consisted in the process of playing immediately, without considering the indications given in the game, as a consequence of that they did not use all the elements in the game, in that situation the teacher had to participate as an exploratory guide of software. Procedure Example:

- **Software Presentation:** The teacher and the students presented the software, Loom and Puzzle, indicating basic instructions to be used.
- **Instructions for the end of the Activity:** The teacher finished and established the maximum time which was 45 minutes for both activities and indicated that they had to answer a brief survey about the software.
- **Students' software exploration:** The primary student started to explore reading the instructions; they pressed all the bottoms that were presented in the software interface. The student started in an intuitive way, to test any bottom that was presented in the interface, discovering the way how to play and the game options.
- **Survey:** At the end of the activity the teacher gave them a survey and he asked them to remember the process that had lived, in that way they would have the possibility to answer the questions related to the usability and learning.

**4.1.2 Secondary school groups:** The students from secondary schools, that is to say, teenagers from the 9<sup>th</sup> grade, presented a similar pattern, which consisted in a more detailed exploration process than the primary students, so the most of the students tested the whole instance in each environment, making the process slower but funnier and more fascinating.

They get the maximum advantaged of the software due to the experience that they get through the acquired skills from games and traditional technology. Procedure Example:

- **Software Presentation:** As in the primary schools, the teacher and the students presented the software.
- **Instructions for the end of the activity:** The teacher explained the last steps of the process as in the primary schools.
- **Student's software exploration:** The secondary student started to explore all the instances, the objective was to get relevant information of the topic, due to the experience that the student has about this kind of technology. They read all the instructions and the information presented by each photograph, in order to get the best conclusions and tested the game in a intuitive way, discovering some aspects that were not discovered by the primary students using an intuitive way, for example; the audio-visual help.
- **Survey:** At the end of the activity the students were given a survey, and the process was the same as the primary students.

#### 5. RESULTS

The evaluation of the software has a quantitative and qualitative character, in an intentioned sample of primary students from a public school and a private school of Arica-Chile.

##### 5.1 Evaluation Usability and satisfaction levels

With respect to the software functionality, the students were divided into two categories for the analysis, primary and secondary, that is to say, children and teenagers. The fact that the process of lasting was one hour; 45 minutes for the use of the application and the rest of the time for the instructions and the survey, was considered before the analysis of the usability evaluation. The purpose of this evaluation was to observe the students interaction facing some characteristics like, user interface, difficulty and entertaining. Besides, the purpose was to find other interesting patterns that the assigned teacher could analyse. To face the interest characteristics of this evaluation analysis, a set of questions in the final survey were performed (were the instructions easy to initiate the game?, was it easy to complete the games?, was the help option good for you? and did you like playing with the software?). With respect to the difficulty level, the figure 14 illustrates the students' opinion in a quantitative way, observing a discussion with respect to the facility of completing a game, the most relevant is that most of the students of both schools find that the game is easy, as long as 12 % (10 students) from the Colegio América (Primary School) think that to complete the game is difficult and the 8 % find the difficulty level as intermediate.

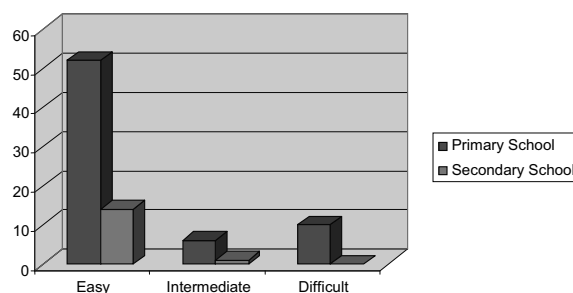


Figure 14: Difficulty Level of the evaluated software



With respect to the facility to understand the instructions of the software, as we have estimated before, most of the students said that the instructions were easy to understand. 90 % of the students said that the instructions were easy. 10% was divided into two groups. 5 % of the students said that the instructions were complicated and the other 5 % did not need instructions.

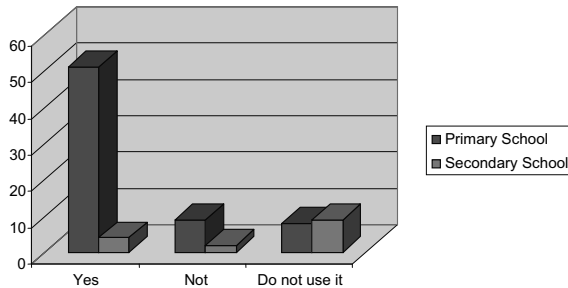


Figure 15: The use of bottom help of the Software

The use of the help button in both applications may have many interpretations, because of the observation before the survey, it was possible to observe that the intuitive attitude of some students showed us that the intervention of any element of help was not necessary, however, in some cases the teacher indicated that the software had help those students who had doubts. Another interpretation seen in the process was the use of help but just to explore this tool, this was the case of the secondary students. So, the following illustration, figure 15, shows that the 62% of the primary students from a total of 66% expressed that the button help was useful because they didn't know how to use some software options, while the 11% of the students used the button help but it was not useful for them. Another important fact is the considerable amount of secondary students that didn't need the help to use the software.

The figure 16, illustrates the level of satisfaction of both groups of students, just one student didn't give an opinion, on the other hand 82 students liked the Software. The satisfaction levels that each student presented, could establish the proximity that the presented information has in a funny way, as the games like the puzzles. All the illustrations and conclusions that were obtained in this analysis proved that the use of educational software is according to the satisfaction that a student requires to use educational software through the entertaining.

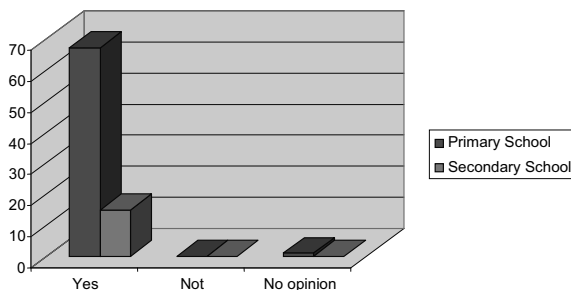


Figure 16: Software Entertaining

As part of other patterns, it was possible to observe the different skills that the students presented, for example, for the Andean students was easier to assemble the weavings faster than the

classmates, in the case of the puzzle, in that way it was possible to observe that some intuitive aspects came from cultural origins, related to pre-Hispanic culture seen in this activity.

## 5.2 Learning Result

To evaluate the result of the learning, an item was considered in the survey, which defines how much they had learned about the kind of Andean clothes. The following questions were set for this, the first question: What is this weaving? Next to an illustration of the weaving and the options (Tari, Chuspa, or Bolsa-Faja), then some open questions (what is a Tari?, what is a Chuspa and what is Bolsa-faja?).

In the figure 17, you can observe the effectiveness of the learning through games, because it could be established that most of the schools, both levels, were able to associate the shown weaving with the respective name, 98 % of the students could associate the weaving with its type.

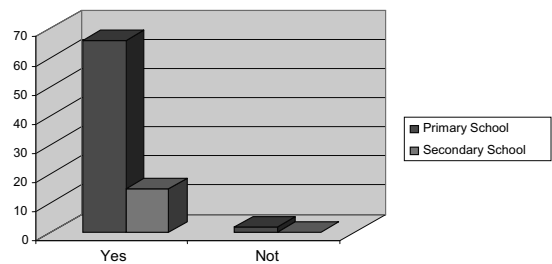


Figure 17: Weaving Correspondence

With respect to the open questions, the students that had to evaluate were able to relate the weavings images with those that were used. It was possible to appreciate in the Andean students' answers that it was easier for them to play and interpretate the Andean weaving and their contexts in which they were used.

The teacher who was in charge of the activity made successful conclusions of the learning process, because the students showed a bigger interest, than in other moments in which they learned through traditional activities.

## 6. CONCLUSIONS

This integration between the puzzle and the Andean loom, produced a bigger interaction that allows a more entertaining learning of the designs, use and customs of the pre-Columbian weavings, at the same time, it allows the possibility of having access to the pre-Columbian referring located in the San Miguel de Azapa Museum. The learning virtual environment facilitated a stimulus to observe more carefully designs and meanings of the weavings, and the application of knowledge on the originals weavings when they visit the museum next time.

From the point of view of the usability, as it was shown through the surveys, the simplicity and a direct environment was privileged in the software, so the student could get familiar with it in a faster way, this could be observed through the fact that only the students from 4<sup>th</sup> grades needed the help system, besides they chose the outstanding and high cultural value weavings, which are commonly used in ceremonial rites of the Andean ethnics. It was possible to appreciate that the students

wanted to solve a more difficult puzzle with Andean relevant icons in order to exchange experiences with their classmates.

In general the tool is an effective platform for a better learning. The purpose is part of an educational programs of the San Miguel de Azapa Museum Arica-Chile, and it is integrated in a software with a bigger largeness, under name Aymara "Chuymampi sawuña", which means "weaving with the heart". In a specific sense, these virtual games must be a show window to the world, so they must be in the WEB, while the San Miguel de Azapa Museum will have a local show window of virtual games.

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**ICT**



## TOOLS FOR A DIGITAL READING OF ANDREA PALLADIO'S *I QUATTRO LIBRI DELL'ARCHITETTURA*

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### ABSTRACT:

The paper describes a project having the goal to generate an instrument which could be able to superimpose to the original edition of Andrea Palladio's Four Books of Architecture (Venice, 1570) – the most influential text of architecture over time - a brand new web-based interface in order to offer a more organic and transversal comprehension of its contents. Otherwise the new edition, as a knowledge information system, it's much more interesting than the former static 2D book page and shows the typical Palladian multimedia contents. Finally, Palladio's main drawings are converted in a 3D space using 3D modeling techniques showing directly the two-way illustrated (text and drawing) character of his own architecture.

## 1. INTRODUCTION

### 1.1 The problem of a new Palladio's treatise edition

Andrea Palladio's *Four Books of Architecture* (Venice, 1570) is his influential architectural testament, in which he set out his formulae for the orders, for room sizes, for stairs and for the design of details. In the *Fourth Book* he published the restorations of the Roman temples which he had studied most closely, and in the Second and Third Books (as no architect had done until then) offered a sort of retrospective exhibition of his own designs for palaces, villas, public buildings and bridges. Using a concise and clear language, and an effective communication of complex information through the co-ordination of plates and texts, the *Four Books* represents the most effective illustrated architectural publication up to that time. The 'interface', which Palladio offers to his readers, has no equals in texts of other Renaissance architects and in books of the same kind in the following centuries. It was therefore not only Palladio's architecture, with its rational basis, it's clear grammar, its bias towards domestic projects, but also the effectiveness of his book as a mean of communication leading to the immense influence of Palladio on the development of architecture in northern Europe, and later in North America. The richness of Palladio's text has always led to the reader's interpretation (which was often difficult) who had to understand two-dimensional drawings which were conceived as 3D models but were confined by force to a two-dimensional space, as well as drawings which require a precise and knowledgeable method of reading in order to be interpreted, or drawings which explain the text which, however, present a strong ambiguity in themselves, or a marked distance from the text to which they refer. A new version of *I Quattro libri dell'architettura* was requested in order to insert itself into the long tradition of Palladian editions, starting from Fréart de Chambray to those of Giacomo Leoni with comments from Inigo Jones, to those of Benjamin Cole to Bertotti-Scamozzi, until the latest edition edited in Italy by Hoepli, endowed however, with the necessary means of giving a new permanent and solid clarity to the contents. On the other hand, as a typical project-related resource in a networked and online environment, the Palladio's treatise requires therefore different cataloguing, retrieval and visualization rules and tools drawn from those elaborated for

traditional documents. In the design field it's essential to perceive, compare, organize, link and interpret as many forms of knowledge expression as possible within a community, bringing people together around a pool of quality information.

Therefore the problem of a new Palladio's treatise edition is a problem that present two different sides:

- A new clear interface for the basic elements (typically images, texts of the book and his demonstration);
- The construction of a new information system able to overcome an extremely limited access to related documents (mainly due to difficulties in moving and handling documents), the fragmentary nature of document locations (often dismembered and lost), the unfeasibility of statistical and quantitative research, and the limitations of describing a 3D object.

These considerations are sure useful for the Palladio book, but can be applied generally to all Renaissance architectural treatises. The tool illustrated here therefore, although strongly characterized on the Palladio work, can be employed also in the transposition of others publications of the same type.

### 1.2 The new framework for the edition

A banal solution of the problem of a new digital edition of Palladio's *Four Books* will be founded in a simply 2D digitized and OCRed version of the text, implemented like html text or a PDF file. A more sophisticated solution will be generated maintaining the layout of the original document, to which will be added multimedia or interactivity, and links to glosses of words and phrases which appear when the user moves the cursor over the text. Typical additional features will be the capability of adding an annotated text, including insertion of images (found through image searching) as glosses, of creating personal wordlists and online vocabulary exercises constructed from personal wordlists. Finally a more general, robust and interesting solution is to reconstruct the original text like a database which could be helpful in improving the effectiveness of the system as a practical tool for users. Increasingly, Rich Internet Applications (RIAs) are being used to display text more dynamically and with added options. RIAs could allow to give a new light to the text contents and a new level of

transmissibility and to facilitate the access to the book's information.

Our project based on RIAs represents an instrument which could be able to superimpose to the original edition of *The Four Books* to a brand new web-based interface in order to offer a more organic and transversal comprehension of its contents. Moreover, the new edition, as a knowledge information system, is much more worthy than the former static 2D book page and shows the typical Palladian multimedia contents.

At the moment the new edition is implemented as a DVD application with all the contents (database, images and models) included in order to be directly consultable on site. This choice, motivated by the size of images that could cause a slowing down of the system during the remote access phase also using ADSL connection, does not preclude a new web-based version which gives access on the Internet in order to obtain information on-demand with typical client/server architecture.

In front to the traditional approach of single transcription of the document (such as CD Art Theorists Of The Italian Renaissance), or in the most recent outcomes as e-books and digital library projects promoted by Google and Microsoft, work will not be limited the creation of a hypertext, but an integrated system of text, illustrations, animations interactive 3D models.

The experimentation developed here around the Palladio work can be with facility extended to other Renaissance architectural treaties for the homogeneity of the types of content in these publications.

### 1.3 3D models vs. 2D drawings visualization

Digital 3D models involve a high-potential technique. Although creative, modeling is strongly rooted in knowledge acquisition. 'Creation' has to be similar to reality even if cognitive data can be differently used depending on the adopted modeling technique. 3D virtual models are a break with the past limits of projection and cross-section, and with the analogy between the sheet of paper and the surface of the wall, since they presents a world that is more similar to our perception of it. For the architect – an operator which thinks in spatial terms first of all – the use of a 3D model as a representation method is a great improvement in order to document a building design, starting from the creation of textual and visual database with hypermedia and multimedia possibilities that allow to collect and integrate huge quantities of heterogeneous architectural data with easy access, to extremely complex data structures and constant user guidance (Gaiani, 2000) (Davenport, 1996). Secondly, the use of 3D real world models instead of 2D drawings provide perceptual as well as conceptual representation. Much more than an instrument for building up a final image, as it is usually considered, they afford a much wider range of representation, becoming part of a 'manipulability system', capable of revealing the intimate structure of the objects depicted. Models are 'systems of symbols comprising the properties that are characteristic of experience but that can be manipulated, unlike experience can'. Experimenting with the models, we can examine what would happen in the event of particular modifications and get a better understanding of behavioral aspects that are not immediately apparent on empirical observation. Finally, models are an excellent means of understanding architecture, describable as a collection of structural objects, and identified through a precise

architectural vocabulary, (Mitchell, 1990). An 'architectural knowledge representation' is one that describes a series of structured objects using a specific architectural lexicon. This can be seen by using a classic example, the plates of *I Quattro Libri dell'architettura* by Andrea Palladio, by explaining methods and levels of precision both in the restoration of the general form as in the details and how to reassemble the parts to reform the whole. By constructing digital models as part of a recognized architectural means of communication, it is possible to extend the concept of 2D GIS to that of 3D GIS, so that every model isn't simply a mould, but an informative system able to give back the various properties of the object and analyze its spatial qualities. For these reasons Palladio's main drawings are converted in a 3D space using 3D modeling techniques showing directly the two-way illustrated (text and drawing) character of his own architecture.

### 1.4 Statement

The problem of a true multimedia edition of a complex text of architecture like this is much more complex than a simple image-based or video-based or 3D retrieval model or an application with static cross links between images, text or interpretative models. The goal is to build a visual multimedia database made of documents containing images and text with different types of access, possibility of individual paths, multiple searches both on text and images, comparative analysis of different kind of materials.

This paper introduces our application describing the character of the original edition and the context in Section 2, the problem statement and the objectives of the edition in Section 3, the technological underpinning and the development framework in Section 4. In Section 5 we will face to the system description. Finally Section 6 concludes the paper with some remarks for future developments.

## 2. BACKGROUND

### 2.1 Andrea Palladio's The Four Books of Architecture

*I Quattro libri dell'architettura* are structured in such a way as to form a sort of architects' manual, organized as a knowledge system. In the first part of the text, basic principles of architecture, the words that architects use, the architectural orders and their declinations, the preferred proportions, the choice of materials and their usage, are illustrated. Palladio then proceeds with a catalogue of his principal works for private clients, palaces and country villas, followed by public buildings. Finally the last part shows a repertory of ancient sources with measured drawings of Roman ruins. One of the novelties introduced into *I Quattro libri*, is the presentation of Palladio's own architecture, proposed as an emblematic case to use as a model for further works. This is a revolution that on one hand promotes Palladio's architecture, but seen in prospective, pushes to assume not only antiquity as a reference, but as a rereading, as it took place in the sixteenth century. The treaty is enhanced with numerous images which almost always have measurements, placed together on a page with a text that describes the various elements, and not simply as a plate separated from the context. Palladio does not limit himself in proposing special examples but tries to generalize his teachings to render them universal, introducing the capability of the individual architect in managing to adapt the general solution to the specific case. The writings, especially in the first book, offer

a wealth of examples and proportional relationships with which it is possible to create an architecture which is correct from the formal point of view. These proportions can be exploited, supplying the means that permit a simple application even with a modern unit of measure.



Figure 1: Frontispiece of the First Book of *I Quattro Libri*.

## 2.2 Rich Internet applications (RIA)

Rich Internet applications (RIA) (a term introduced in a March 2002 Macromedia whitepaper) are web applications that have the features and functionality of traditional desktop applications. RIAs typically consent to transfer the processing necessary for the user interface to the web client but keep the bulk of the data (i.e., maintaining the state of the program, the data etc) back on the application server. RIAs offer a greater functionality within a browser and are less dependent of the server, compared to traditional web pages. Moreover, they can offer the same functionality as standalone desktop applications. The delivery and maintenance costs of RIAs are low compared to standalone applications, since they require no installation, updates or patches. RIAs have a high degree of availability and flexibility, since they are accessible worldwide where networked computers are available. RIAs are platform independent; however some RIA platforms require a browser plug-in. RIAs offer the same functionality as standalone applications, and as web-based applications, therefore they even offer bigger advantages (Noda, and S. Helwig, 2005) and for this reason have been chosen as the framework for the new edition. Because the definition of a RIA is not fixed and framed, there are several platforms that can fit the definition from Wikipedia: 'RIAs are web applications that have features and functionality of traditional desktop applications. RIAs typically transfer the UI processing to the web client, but keep the bulk of the data back on the application server' like Adobe Flash, Ajax, Java, Windows Presentation Foundation (WPF)'.

In this zoo we choose to use a set of Adobe technologies that are a 'de facto' standard, robust, yet which allow easy programming and are easily installed on the clients' computer.

## 3. THE DIGITAL EDITION

### 3.1 Goals

The goal of our project is the creation of a means by which to study and survey *I Quattro libri dell'Architettura* directed on one hand to cover certain omissions of the printed editions which limit the study, and to maintain, on the other, the normal procedure of reading a written text enhanced by a series of useful instruments so as to have a more organic and transversal understanding.

The simple digital conversion of whatever document can never substitute the original, in which, even at a first glance without any further transformation, it is possible to appreciate the text, the images, the care that has been taken, and the format of the pages, independently of the age of the product and of the culture that produced it. The instrument that therefore determines the reason for being, cannot therefore, limit itself to a simple representation of the original projected onto a screen, but must furnish means that compensate for the artificial nature and suggest new ways of reading the document.

The question that has been tackled therefore is the focusing upon of a dynamic method of research which is closed to our mental categorizations based upon researched objects which are not limited to the usual systems of simple written indexes. (Encarnação & Foley, 1994).

In this context one of the main problems that exist, is the lack of a communication standard for multimedia material that allows each scholar to feel comfortable with the digital version of the document. While a printed book always maintains its fascination and interest and whichever person knows how to use it, a computer interface usually requires an initial period of study that often results as being difficult for the more traditionally minded student. The hypothesis which is made is that this layout is not limited by the contents and can be modified through a time which is not synchronized to the database into which the book has been decomposed, but which can be continually enriched as studies progress.

### 3.2 Work organization

Fundamental feature to face during the process of digital translation is the definition of the criteria by which the original is transferred into the electronic format. Main phases of the project were: 1. treaty analysis and comprehension; 2. tools definition; 3. original digitization; 4. platform choice; 5. contents database creation and organization; 6. consultation interface definition and creation; 7. interactive contents creation; 8. 3D models of the architectural elements construction; 9. relationships between the various parts of the treaty, between texts and images, links to the interactive contents and eventually, to other documentary sources creation.

The solution to these problems has brought about a new method of organization and exhibition of the data according to three levels of structuring to which the metaphors of three levels of iconicity correspond: (i). textual indexes according to a tree structure for the parts at a high level of abstract classification; (ii). typical 2D architectural means, such as plans, elevations, sections as metaphors of the spatial system; (iii). static and/or dynamic 3D models which give an higher level of description.



Once realized the software structure at the base of the application (points 2, 4, 6) (reusable also for the digital translation of others treaties), the project phases will be: 1. digitization of the original items; 2. transcription; 3. creation of 3D models; 4. creation of interactive animations; 5. organization of information in the database. Most of these operations can be parallelized, even by different operators coordinated from one studios expert of the treaty. With system arrangements can be made about 80-100 pages scanned per day inclusive of post-processing (Beltramini, Gaiani 2003).

The transcript must necessarily be done manually (type of the original and the language used do not allow the efficient use of OCR techniques), paying special attention to the orthography that sometimes differs from the modern version. 3D models and animations take time varies depending on the complexity from few hours to several days.

The latest operation is the organization within the database of materials produced rebuilding hyperlinks and the links between text, pictures, models and animations. This phase requires the intervention of an expert well experienced of the Treaty. It can be estimated a time of approximately 6 months for the digital conversion of a treaty of medium size and complexity.

## 4. IMPLEMENTATION

### 4.1 Technological platform

The choice of platform used to develop the project was one of the crucial aspects of our work. The aim fixed from the start has been a multi-platform application which could to be used on-line. The following have been considered as base requirements:

1. High level object-oriented programming language;
2. Application platform-independent;
3. Libraries for *networking* availability;
4. Safely code execution from remote sources;
5. Easy implementation and updating.

Adobe Flash has been judged an appropriate authoring environment to create our highly interactive and visual environment. All the interactive contents have been created with Adobe Flash, exploiting the interaction at script level between main application in Adobe Integrated Runtime (AIR) and SWF content dynamically loaded. Adobe AIR ([www.adobe.com/products/air/](http://www.adobe.com/products/air/)) is a cross-platform desktop runtime that allows web developers to use web technologies to build and deploy Rich Internet Applications and web applications to the desktop has been used. AIR allows the integration of Flash, HTML, PDF and database using Actionscript as programming language. We used AIR Flash, to overcome the lack of database and 3D graphics support in Flash. AIR applications can operate offline, and then activate further functionality or upload data when an active internet

connection becomes available. Adobe AIR includes (i) an embedded, cross-platform, open source SQLite local database (<http://www.sqlite.org>) which requires no extra setup while providing large data capacity and full text search, (ii) WebKit, an HTML open source library used for visualizing the contents. The main tool for the development of AIR application is Adobe Flex, a free, open source application development solution (based on Eclipse) for creating and delivering cross-platform RIAs within the enterprise and across the web.

The management of the 3D graphics has been left to the PDF standard using Adobe Acrobat 8.1 which is embedded in AIR. Acrobat 3D is founded on Universal 3D (U3D) file format, which is a *de facto* standard for visualize exchanging 3D information, and which is widely used by all the manufacturing industry. The format defined by the 3D Industry Forum Consortium has been standardized by 'Ecma International in 2005 as Ecma-363. U3D – and also therefore 3D PDF – support an extremely efficient compression technology which, above all, provides a compact representation of complex objects which are typical of architectural elements, taking advantage of the runtime library while implementing compressions, streaming, *Continuous Level of Detail*. Acrobat integrates the potential of the 3D model with the possibility of visualizing the structure of the object, take measurements, and add notes.

### 4.2 Database system architecture

At the heart of our applications is the DBMS (database management systems) based on SQLite. Extending database systems to support multimedia search requires more than 'just' the abstraction from data structures; for, the problem underlying multimedia search is that the DBMS has to reason about the content of multimedia objects as well. Common DBMS have several drawbacks in handling multimedia data (Grosky, 1997) (Santini, & Jain, 1997), i.e. in the indexing that is an important concept in modern database management systems to enhance processing efficiency and retrieval capacity (e.g., similarity searches). The original book analysis has pointed out the need of a very flexible database able to take charge of texts, illustrations, cross links, and multimedia contents, and that could operate under our complex interface. This last requirement conditioned strongly the information organization; because required to map the co-ordinates of the page elements (words and images) within the database so as to be able to superimpose the interactive information over the original image on the screen. The treaty has therefore been broken down into single words, each one recorded in the database. Obviously only the coordinates of the words equipped with visual tools has been indexed. On the other hand, the coordinates of all the lines have been indexed so as to be able to simulate the selection of lines as in a text editor.

The word records have been linked to other secondary tables to manage hypertext links, subjects, and research keys. Likewise

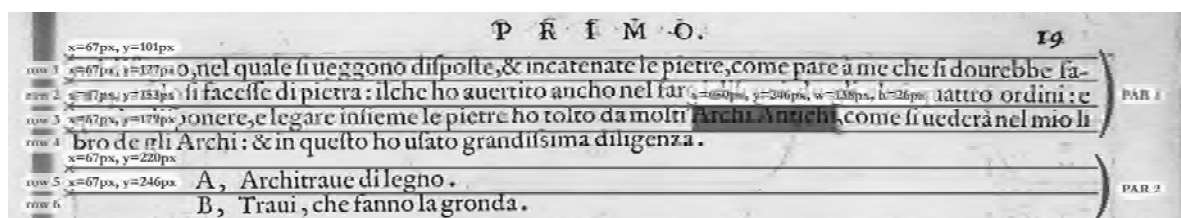


Figure 2: Elements of the Treaty page to be indexing and to be transfer in the database.

the areas of the images have been mapped within a specific table in the database linked with the subjects and research keys.

The SQLite database will be interrogated with standard SQL-query. The records of the different tables are directly associated at database level through the definition of 'view' which simplifies and optimizes the syntax of the interrogations. As every word is a single record, the results of a search/visualization are processed by a routine which rebuild organization, formatting and spacing of the paragraphs. Every page is made up of hundreds of words so special attention has been paid in choosing the field to be indexed, in order to balance, on one hand, the slenderness of the database, and on the other, the speed of access to the information.

Research in the database takes place by terms, with the possibility of finding all the words which have been indexed or only the paragraphs that contain at least one of the words. The use of a jolly character is admitted. In order to simplify the search, some original terms have been added with a modern version of the same term (eg. *Toscano*>*Tuscanico*, *basa*>*base*). The images have been equipped with a verbal description to be used in the query. An index of places and names complete the equipment of the search tools.

### 4.3 System implementation

The whole application has been developed exploiting the runtime environment of Adobe AIR and written almost entirely using Adobe Flex Builder 3 and Adobe Flash CS3, programming the core in ActionScript 3. The interactive parts associated with the individual pages have been made up with Flash CS3 exploiting the software's ability to hand draw those parts of the image wished to be put into evidence. The relationship with the Flex has been assured obtaining single clips published in Flash by an abstract class Actionscript. This class manages the mouse control in a homogeneous way for every interactive content, highlighting images areas and recording specific buttons in the whole interface. The textual interface uses the HTML viewing engine (WebKit) supplied by AIR. HTML code is made up from a collection of templates filled using DHTML through a calls interchange between the HTML layer (Javascript) and the application (Actionscript). The database is managed by the SQLite library and is queried using SQL language. A rewriting of the access module of the database, querying a db server (type MySQL) or a web server which gives back an XML structure, allows an easy porting of the application in a web environment. The implementation of the information within the database involved the writing of an XML parser which interpreted the XML files used to describe each page of the treaty and its contents. A customized version of the interface has enabled the visual mapping of the words areas.

Models visualized with Adobe Acrobat have been made with a commercial freeform modeler and successively imported in U3D format. The models have been semantically broken down so as to allow the user interactions with each architectural element. The 3D PDF file has been programmed using Javascript to interact with 3D models accessing model's information and working collaboratively with the main interface. Every element of the model has been associated to a Javascript code which manages the interactivity. Hence the models are an interactive content: parts can be put into evidence changing the characteristics of the materials or isolating them

from the context. It's possible to move from one viewpoint to another predetermined one or explore the model in real-time.

## 5. THE SYSTEM

### 5.1 Original book digitization

During the ascertainment phase, the digitalization of the original has been undertaken making reference to a protocol defined when the project for the digitalization of the complete Palladian corpus document was implemented by the CISA - Centro Internazionale di Studi di Architettura Andrea Palladio in Vicenza (Italy) - between 2001 and 2003 (G. Beltramini, M. Gaiani, 2003). Due to the well-known skepticism of the scholars towards manipulated copies, a need was felt to supply the user with a precise reproduction of the original, without any modification either in color or in a downgraded resolution, in order to improve the interactivity. The conservation of the finest details has been undertaken by a visual examination of representative samples. The frequency of the spatial sampling has been selected as parameter to adequately preserve all the relevant details of the images, following the Nyquist-Shannon sampling theorem. As the Treaty was originally printed by xylograph, there are no very fine or close lines or hatching, so that there has been no particular problem during the scanning process. The level and range of the color has been determined with reference to the color space of the object. The requirements for the quality of the reproduction have been defined with reference to the output device, that is the screen, using the color space sRGB described by the IEC 61966-2-1 normative as a default color for multimedia applications, in so far as it is a robust and consistent solution when used in web applications. Attention has been paid to the maintaining of measurements and proportions of the pages, in order to allow for correct future measurements.

The digitization has been undertaken using a Mamiya 645PRO equipped with a Jenoptik Eyelike M6 which when used in the 16shot mode, produces 6.144 x 4.096 pixel images which can be stamped in a 430 x 290 mm. format at 340 dpi minimum. This guarantees the possibility of a reproduction on paper of the Treaty true to the original without any interpolation. The color calibration has been undertaken using the 24 colors Gretag Macbeth target. The Kodak Grey Scale Control Patch Q13 - which contains a metric and imperial scale, which gives an optimal dimensional reference - has been used as a reference target during the acquisition phase for the white balance. The required resolution (0.2 mm from the actual plane of the page of the book) has been verified by the MTF measurements of the system. The technique of the slanted edge, which conforms to the accepted ISO standard, in particular the ISO 12233, has been used in our case. Finally the recorded images have been subjected to homographic rectification to correct the rotation due to non-alignment during the recording phase, a necessary situation caused by the wish to not ruin the binding of the book.

### 5.2 New tools

The study of the original book and the control with a target user has made it possible to define the tools which must be developed in the digital edition: 1. Cross-links within the Treaty; 2. External links with other documents (such as Vitruvius's Treaty and later editions of the Treaty); 3. Measurement tools using also unit like Vicenza feet and meters which allows distances measurements, both on a real

scale and on a drawing scale; 4. Units conversion tools (in particular between Vicenza feet and meters); 5. Proportional relationships between architectural elements viewer; 6. 3D models of the architectural orders using a semantic subdivision of the parts; 7. Comment and markup tools; 8. Bookmarks tools; 9. Comparative analysis of the pages and/or different illustrations tool.

The development of a visual retrieval system for 2D and 3D is a long-term objective and has not been implemented in this first digital edition, but it is also essential to have a textual retrieval system in order to provide a unified integrated access to data.

Our project indexes every word in the text, while the development of a term-based approach using a thesaurus has been implemented. There are practically no thesauri in Italian specifically created for the field architecture or archaeology. It was decided to develop an in-house thesaurus for our needs, selecting and organizing terms according to the main issues in the project creation starting from the Art & Architecture Thesaurus del Getty Institute, created in 1990, vocabulary of terms and other information which is used to catalogue works of art, architecture, decorative arts, written material and archives, images, cultural material objects, covering a span of time that goes from antiquity to the present day. Unlike current automatic thesauri, manual thesauri improve the precision for descriptions and subject access to resources, enabling more exhaustively, specificity and flexibility than classification and subject headings. Their creation is easy for traditional textual material, while is complex for 3D Virtual World and 2D animated graphics, which hasn't been created to be catalogued and in which textual data are implicitly contained but not explicitly declared (Paquet, Rioux, 1999). Our Thesaurus has been developed, in accordance with ISO 2788 and 5963 international standards, which can be formed consistently with the original objectives of this instrument, as the moment of mediation and creation of agreement within the design community and operate as a key giving access to analogue and digital resources organized in a file.

### 5.3 Application interface

The main element of the interface is obviously the page visualization. To give the maximum space to the page we reduced the graphic elements such as icons and panels to a minimum, so as to avoid distracting the user and oblige him to learn how to use numerous functions. The image of the page, which faithfully copies the original, is simply enriched by a series of symbols and colors which make hyper textual links, in-depth and interactive contents, more evident. The page can be enlarged and explored by means of a preview which show the area visualized at the moment. The interface solution is tightly connected to the technology which it uses (*see 4*).

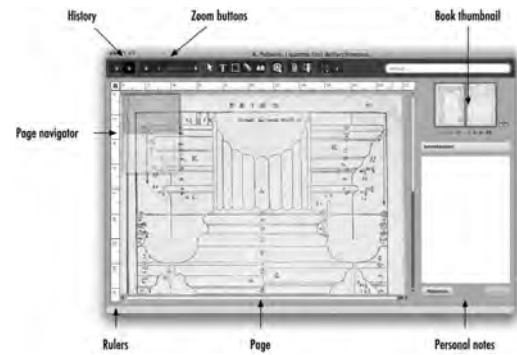


Figure 3: Application interface.

#### 5.3.1 Page representation

Every page is organized as a series of layers which are overlaid by different features on the interface: a. Page image with multi resolution support; b. Selection layer; c. Interactive elements; d. Measurement system.

**Page image:** The lowest level contains the page image. This is made up of a mosaic of many square areas (9 columns and 13 lines) which create a 32-bit image in PNG file format. To overcome the Flash poor quality of the algorithm of image scaling, we supplied three sets of images at different resolutions automatically implemented according to the actual consultation factor of enlargement.

**Layer selection:** The mouse selection is managed by a layer placed above the image layer. The user could highlight parts of images or texts to be copied into the notes, like in a text editor or graphic software. The system simulates the selection of the text which in reality is never shown but only recovered from the database. During the copy/paste process, the current formatting is maintained, even when original parts are inserted into the tables. The selection of parts of images can be copied into the notes, saved in JPEG format or opened as a separate window to be compared with other pages.

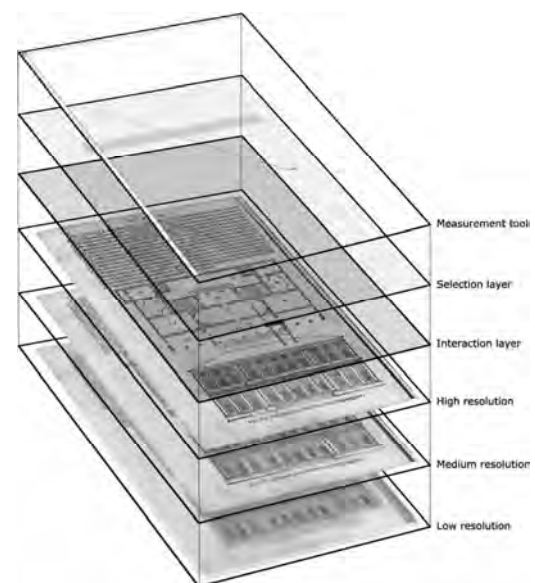


Figure 4: Organization by layer of page elements.

**Interactive elements:** A transparent layer with interactive elements can be found above selection level. There are two types of interactive elements: defined at database level (cross-links, external links) and specific of the page under examination. These elements are dynamically loaded Flash movieclips which interact with the user overlapping hatchings, notes, etc.

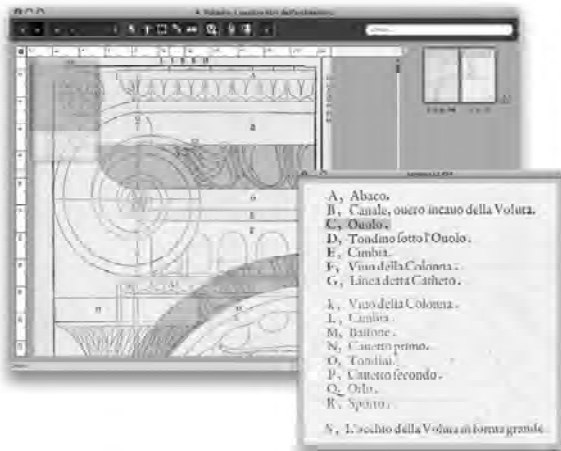


Figure 5: Highlighted architectural elements mouse sensitive.

**Measurement methods:** At top level is the measurement tool. This is made up of a series of scale rulers placed on the side of the page and by a dynamic line which can be traced by the user to establish the distance between two points and the angle of inclination. The tool is precalibrated to measure the page in centimeters according to the original dimensions. Depending on the content of the page, different areas can be supplied which are characterized by different scales and units of measurement. In this way, in the case of the drawing of a building, the application will allow measurements to be made in both feet and meters and switch from one to the other. The scale rulers,

besides adapting themselves to factors of enlargement, are subdivided according to the measurement system. The user can define his own terms of comparison while undertaking measurements defining an autonomous measurement unit. In this way different proportion hypothesis could be evaluated.

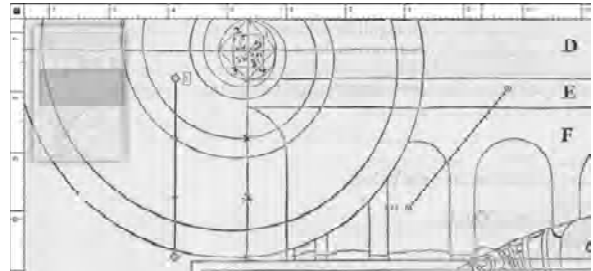


Figure 6: Measurement tool.

### 5.3.2 Written version of the page

In order to give quick access to the contents without loading the correspondent high-resolution image, an alternative visualization is available which simply shows the plain text with, if available, lightened drawing images. This allows not to constantly request information from the DVD and save long times of latency. The smallest images dimension has been obtained by reduced dimension, scale of grey and JPEG format.

This system is achieved by rendering the page through the web browser that is incorporated within our framework. The use of HTML file format for the visualization allows to maintain many of the interactive instruments as well as the hyper textual links between the parts.

### 5.4 Interactive contents generation

Interactive contents have been generated according to the characteristics of each specific page. They allow for example

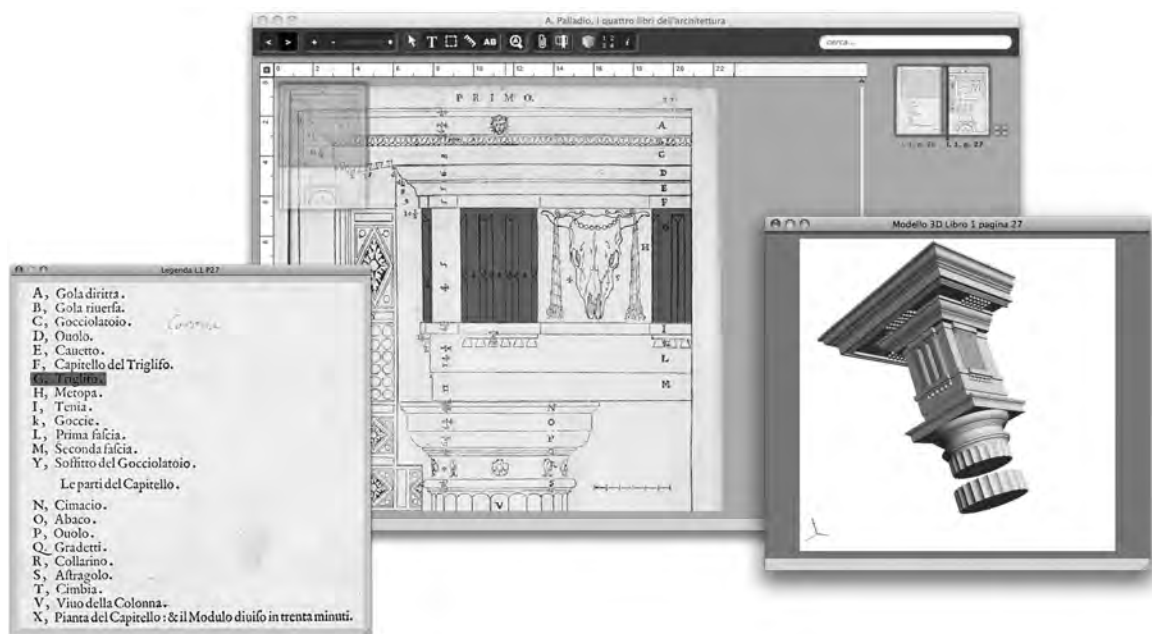


Figure 7: 3D model of the Doric order following the Treaty. On the left a floating window with the legend of parts.

to: 1. highlight areas of images at cursor over; 2. bring into evidence construction lines; 3. determine with ease proportional relationships; 4. open windows with more detailed sources of information.

The user also has the possibility of forming bookmarks and creates indexed notes within the database. This feature, together with the integration of information from the Barbaro edition of *I Dieci Libri dell'Architettura* by Vitruvio and plates from the seventeenth century edition of the treaty, highlights the capability of the application to organize and mix large quantities of data which come from external sources.

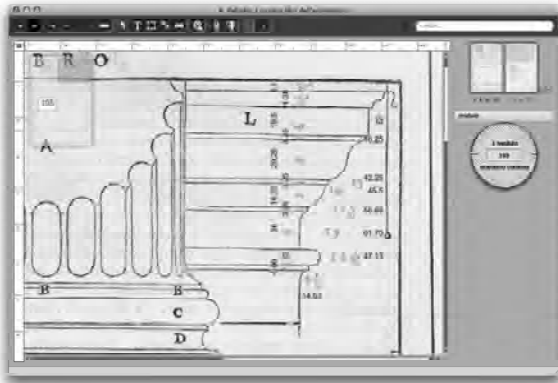


Figure 8: Example of interactive elements over the page. The system recalculate the original dimension of order elements by a custom user base measure.

### 5.5 Links

The application presents links to the following ancient books: Vitruvio, *I dieci libri dell'architettura. Tradotti & commentati da Mons. Daniel Barbaro*, Venetia, F. de Franceschi senese e G. Chrieger alemanno compagni, 1567; Muttoni F., *Architettura di Andrea Palladio vicentino arricchita di tavole*, Venezia, A. Pasinelli, 1740-1748; Bertotti Scamozzi O., *Il forestiere istruito delle cose più rare di architettura[...]*, Vicenza, Vendramini Mosca, 1761; Bertotti Scamozzi O., *Le fabbriche e i disegni di Andrea Palladio [...]*, Vicenza, F. Modena, 1776-1782. All these publications have been digitized following the same protocol of the *I Quattro libri*, and have been embedded in our digital using the scans of the original.

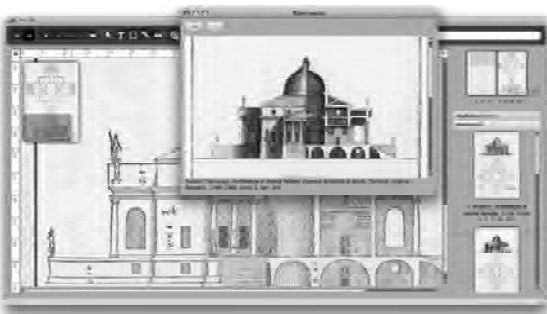


Figure 9: Links between the Four Books and F. Muttoni's *Architettura di Andrea Palladio vicentino arricchita di tavole*.

## 6. EMERGING RESULTS OF DIGITAL READING AND FUTURE WORKS

A comprehensive applications of new tools here designed allows a detailed reading of the *I Quattro Libri* contents.

One of the aspects that the analysis using the new tools has put in evidence has been a partial lack of correspondence between the indicated dimensions on the tables, and the effective drawn dimension. In order to calibrate the measurement tools have been measured the distances in centimeters of the sheet correspondents to the several quotas of a table to get an average value to attribute to the foot or module with which the drawing is quoted. This operation has evidenced an appreciable discrepancy between the measures set out and what is drawn: in fact for some distances the tool finds the exact measure, for others obvious differences are noticed. Such phenomenon is mainly visible in the building drawings where, in effects, the illustration is relatively small and schematic, while he is smaller, but not completely absent, in the tables of the orders.

In conclusion we can say that today RIAs make it quite easy to create new editions of Renaissance treatises which are certainly one of the most important sources of information for archeologists in Roman architecture studies like information system and analysis tool. In the specific case, the new edition of Andrea Palladio's *I Quattro libri dell'architettura* brings new in-depth 'within' the text, 'through' the text, and 'between' different texts. Much work remains to be done to arrive at a new type of edition that we could identify like a completely new system compared to the printed treaty of architecture. Specifically: 1. English and French edition (multilingual both in the interface and the contents using the oldest translated editions of Palladio's treaty); 2. Extend the number of the models and search inside the models; 3. Cross references with the Marco Vitruvio Pollio treaty; 4. Build an on-line version.

Other future development will be in the direction of overcome the typical RIA's limitations like we could found in literature: 1. Client processing speed; 2. Script download time; 3. Loss of integrity; 4. Loss of visibility to search engines; 5. Dependence on an Internet connection; 6. Accessibility.

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# MULTISPECTRAL ACQUISITION AND ANALYSIS OF ANCIENT DOCUMENTS

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**KEY WORDS:** Multispectral Imaging, Image Registration, Document Analysis, Document Enhancement

## ABSTRACT:

Digital imaging for ancient documents has gained significant interest in recent years. It opens new possibilities in analyzing, preserving and presenting the content of our cultural heritage. Using multispectral imaging techniques in combination with digital image processing allows on the one hand enhancing the readability of “hidden” texts (e.g. palimpsests, vanished or damaged text due to environmental effects like mold, humidity or fading out of ink) and on the other hand automated investigation of the structure and content of the manuscripts. The content observed can be presented to the public in virtual libraries whereas the original versions are safely archived. This interdisciplinary project paper reports a collaboration of philologists and computer scientists devoted to the recording, investigation and editing of two medieval Slavonic manuscripts of extraordinary importance. First of all, the project deals with the development of techniques for the recording, registration and combination of multispectral images. The main goal in collecting the multivariate image data is to increase the readability of the text written on parchment. The results of the enhanced images are used for the subsequent computer aided segmentation of the page layout (e.g. ruling scheme) and a computer aided script description and stroke analysis as well as the reconstruction of the scripts. The algorithms developed shall enable the philologists to perform their tasks more precisely and faster.

## 1. INTRODUCTION

The need of digitizing ancient manuscripts has different reasons in cultural heritage applications: on the one hand it allows generating virtual libraries\*\* and on the other to permit the public to see ancient manuscripts of interest whereas the original versions are safely archived in the museums/libraries. In comparison to the traditional analogue photography digital images have the advantage that they do not degenerate over the time and can be transmitted to other places with a small effort. Additionally it may be expected that in the long run the decipherment, study and editing of such sources will be done predominantly based on images; a way that relieves the originals and makes their investigation independent of the place of preservation. Furthermore, it may be more exhaustive, precise and less time-consuming through automatic image-analysis tools.

Multi- and hyper-spectral imaging has been used in a wide range of scientific and industrial fields including space exploration like remote sensing for environmental mapping, geological search, medical diagnosis or food quality evaluation. Recently, the technique is getting more and more applied in order to investigate old manuscripts. Three prominent representatives are the Archimedes Palimpsest, Tischendorf's Codex Sinaiticus (the oldest Greek bible-ms.), and the papyri from Herculaneum, Tebtunis and Oxyrhynchus (Provo-project, cf. Macfarlane forthcoming). The main interest of multi- and hyper-spectral imaging in cultural heritage applications is the enhancement of the readability of ancient manuscripts, or palimpsests. A different field of multispectral imaging lies in painting conservation and color science (Saunders, 1988; Burmester et al., 1992).

Nondestructive methods like InfraRed (IR) reflectography are used by multispectral imaging systems to visualize palimpsests or underdrawings (Easton et al., 2003; Hain et al., 2003; Mairinger, 2003). Additionally UltraViolet (UV) fluorescence

techniques are used to enhance the readability of palimpsests (Salerno, et al. 2007; Easton et al., 2003; Rapantzikos & Balas, 2005). A palimpsest is a page of a manuscript that has been written on, scraped off and used again (Tonazzini et al., 2004).

The objects to be edited are two Glagolitic manuscripts (mss.) with Cyrillic and Greek additions of the so-called classical Old Church Slavonic (OCS) corpus, belonging to the new findings made in 1975 at St. Catherine's monastery on Mt. Sinai (Codd. Sinaitici slav. 1/N & 5/N). Since photographic techniques in the visible range (film, digital camera) have proven to be insufficient with the objects given, spectral imaging has to be applied.

This paper is organized as follows: Section 2 reviews non-destructive measurement techniques used for the investigation of old manuscripts. In Section 3 the proposed image acquisition system together with the developed algorithm for the registration of the multispectral images, the enhancement of the readability and the analysis of the folios is described; then follows the conclusion 4.

## 2. NONDESTRUCTIVE MEASUREMENT TECHNIQUES

Electromagnetic radiation is a form of energy that is propagated as time-varying electric and magnetic waves. Characteristics to describe electromagnetic waves are the wavelength  $\lambda$ , the frequency  $\nu$  and the propagation speed  $c$  (the propagation speed of electromagnetic waves in a vacuum is appr. 300000km/s). The relationship between those 3 characteristics is  $c = \nu \times \lambda$ . The electromagnetic spectrum is subdivided in different groups (gamma rays, X-rays, UV range, visible light, IR range, microwaves, ...). Figure 1 (right hand side) shows a visualization of a part of the electromagnetic spectrum, which is subdivided in three different category groups: UV, the VISible

light (VIS) and the Near InfraRed (NIR). According to Max Planck the energy of the radiation is proportional to the frequency of the radiation. Therefore the properties of the interaction of radiation (e.g. visible light) with material can be described by the frequency and the wavelength respectively (Mairinger, 2003).

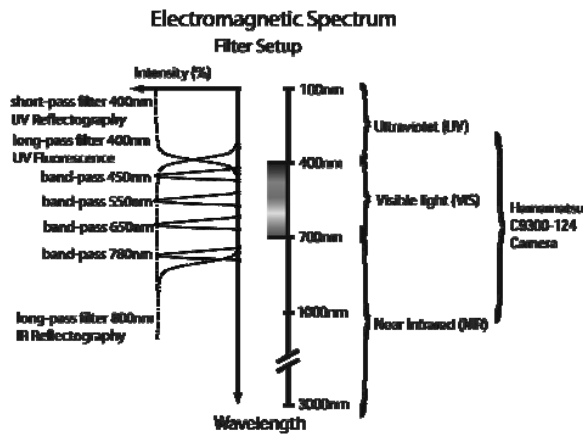


Figure 1: The Electromagnetic Spectrum

The appropriate unit of the wavelength in the ultraviolet range, the visible range and the near infrared range of the electromagnetic spectrum is the nanometer  $1\text{nm} = 10^{-9}\text{m}$ . Gamma rays and X-rays have a short wavelength (and therefore a high energy) and have the property that they can penetrate through materials. Rays in the range of the IR part of the electromagnetic spectrum have the property that they are less scattered than rays in the visible range. Hence the IR part can penetrate materials which are opaque in the VIS range of the electromagnetic spectrum (Mairinger, 2003). Taubert (Taubert, 2003) distinguishes between surface- and depth analysis. For surface analysis VIS and UV can be used, and NIR (low energy cp. to X-rays) for depth analysis. With the use of optical filters the electromagnetic spectrum can be filtered according to the wavelength, such that only a defined band of the spectrum is captured with an imaging device. Filters are defined by their spectral transmittance. The spectral transmittance categorizes filters either in short-pass, long-pass or band-pass filters. These different filter characteristics are defined by DIN Norm 59191 (Mairinger, 2003). Figure 1 (left hand side) shows these three kinds of filters. Short-pass filters have a high transmission in the short wavelength range (passband) and a low transmission in the long wavelength range (blocking range). Band-pass filters have a high transmission at a specific range which is adjacent to blocking regions that have a low transmission. Long-pass filters have a high transmission in the long wavelength range and a low transmission in the short wavelength range. If the slope of the filters spectral transmittance is steep, the filter is called edge-pass filter. Filters with a high quality converge to edge-pass filters. Long-pass filters are used in conjunction with IR reflectography to block the VIS range of the spectrum (and also UV and below) to capture only reflected wavelengths in the NIR range of the spectrum (possible filters: SCHOTT RG 780 or KODAK WRATTEN #87C). For measurements in the VIS band-pass filters are used to select a range of wavelengths of interest (e.g. the green band of the light). Short-pass or band-pass filters are used in conjunction with UV reflectography techniques (the VIS light of the spectrum and beyond is cut off to capture only the UV range of the spectrum; possible filters: SCHOTT UG1 or Kodak WRATTEN 18). For UV fluorescence imaging e.g.

the long-pass filters Kodak WRATTEN 2B or SCHOTT KV 408 can be used. The differences and characteristics of the mentioned filters are described in Mairinger (2003). There exist also liquid crystal tuneable filters in which the spectral transmittance can be controlled electronically (Tomimaga & Okajima, 2000).

2.1 IR Reflectography

In the 1930's a technique called IR photography was developed, which was capable to visualize layers of paintings (underdrawings) below the visible surface (Mairinger, 2003). Because of the limited potentials of IR photography in the range of radiation (the highest sensitivity of IR films is by 820 nm (Mairinger, 2003)) a technique called IR reflectography (de Boer, 1970) was developed in the mid-60s (Mairinger, 2003), which is state-of-the-art today. Sensitive video tubes (called Vidicons) with sensitivity up to 2200 nm can be used for infrared reflectography. These video tubes were replaced by IR sensitive cameras (e.g. IR CCD cameras) because of the main benefits of CCD's (Mairinger, 2003):

- no geometric distortions arise
- sensitive for visible light and NIR (up to 1200 nm)
- high photosensitivity (up to a coefficient of  $10^2$  compared to photographic material)
- output is digitized for further processing

Since the spectral response of silicon based CCD camera ends at 1200 nm where many pigments are still opaque, IR Video Cameras with tubes with a sensitivity up to 2200 nm are still used for infrared reflectography measurements (Hain et al., 2003). Figure 2 shows the principle of IR reflectography. The IR radiation (longer wavelengths cp. to visible light) penetrates the pigment layer and is reflected by the underdrawing layer.

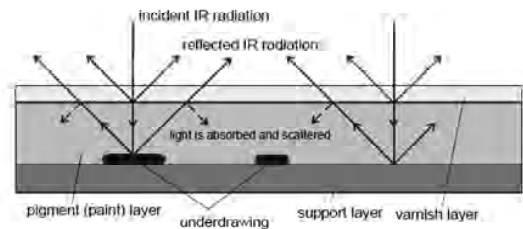


Figure 2: "Penetration of IR radiation in layers of picture", taken from Hain et al. (2003)

A detailed description of infrared reflectography and the mathematical formulation of the reflection is described in Hain et al. (2003); Mairinger (2003).

2.2 UV Fluorescence

Fluorescence is luminescence that is the emission of one or more photons by an atom (or molecule) that is caused by absorbing a certain amount of electromagnetic radiation. The emitted radiation after excitation by VIS or a UV source of radiation has either a shorter, a longer or equal wavelength compared to the incident wavelength. A source of UV radiation is used, since "old paint or varnish layers emits more fluorescence light comparing to newly applied materials (repainting or retouching area)" (Hain et al., 2003). Therefore UV fluorescence is a method to enhance the readability of palimpsests. There are 3 possibilities that can occur if UV radiation is incident on material (Mairinger, 2003):

- the UV radiation is reflected



- the UV radiation is absorbed and is transformed to fluorescence in the VIS range of the electromagnetic spectrum
- the absorbed UV radiation is transformed into heat (no visible luminescence occurs)

Easton et al. (Easton et al., 2003) deal with multispectral imaging techniques, which are applied to the Archimedes palimpsest. To light an object with UV radiation a HQV 125 lamp with a wavelength peak of 375nm can be used. Since optical filters degrade the images spatial resolution of an optical system it is also possible to use narrowband light sources such as LEDs. The use of narrowband light sources additionally reduces the amount of incident light to the painting/manuscript which follows the conservation goal to minimize the incident light dose (Barry, 2007).

### 3. MANUSCRIPT INVESTIGATION

In the following subsections, the techniques for the investigation of the 2 objects to be edited are explained in detail. First the multispectral acquisition system and the registration of the single images (each concerning a different spectral band) is described. After the registration, the spectral bands of a single page are combined to enhance the readability of the Glagolitic text. Furthermore the characters are analyzed and the ruling of the folios is estimated.

#### 3.1 Acquisition Setup

The acquisition setup used consists of a traditional RGB camera (Nikon D2X) and a NIR camera (Hamamatsu C9300-124). Color images and UV fluorescence images are captured with the Nikon camera, which provides a resolution of  $4288 \times 2848$ px. A filter wheel with 7 different filters is mounted in front of the Hamamatsu camera.

Channel	Filter type	Annotation
1	SP 400	UV reflectography
2	LP 400	VIS-IR
3	BP 450	VIS-IR
4	BP 550	VIS-IR
5	BP 650	VIS-IR
6	BP 780	VIS-IR
7	LP 800	IR reflectography
8	RGB	VIS-IR

Table 3. Description of the multispectral images containing the channel number, the filter type, and the methodology of the image acquisition. LP depicts a Long Pass filter, SP a Short Pass filter and BP is a Band Pass filter

The filters used are summarized in Table 3 and the spectral transmittance of the filters is visualized in Figure 1 (left hand side). Four band-pass filters with a peak of 450nm (blue), 550nm (green), 650nm (red), 780nm (NIR) and two long-pass filters with a cut-off frequency of 400nm (UV fluorescence) and 800nm (IR reflectography) are used. Additionally, a short-pass filter with a cut-off frequency of 400 nm to capture UV reflectography images is embedded. The Hamamatsu C9300-124 camera has a spectral sensitivity from UV to NIR (330nm - 1000nm) and a resolution of  $4000 \times 2672$  px.

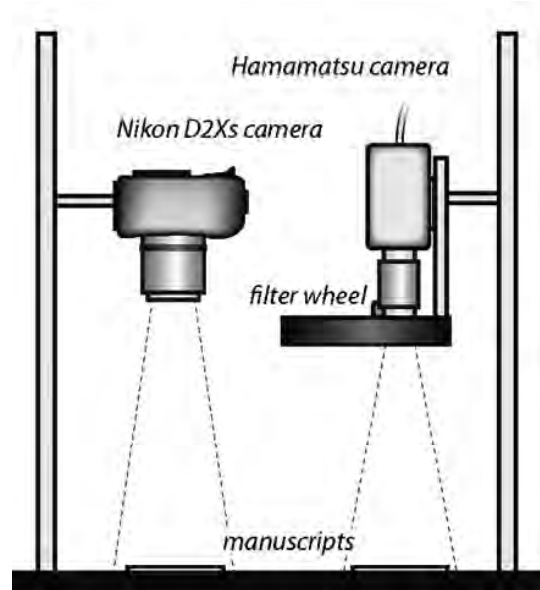


Figure 4: Acquisition Setup

The alignment of the two cameras is shown in Figure 4. This setup leads to a spatial resolution of approximately 550 dpi for the images of the Hamamatsu camera and a resolution of approximately 500 dpi for the Nikon camera. Since every folio is captured with both cameras, a shift of the page between the cameras is necessary. Therefore, a registration of the images is done.

#### 3.2 Registration

Both Nikon images are coarsely registered to the reference image (channel 8) by an affine transformation. This compensates the rotations caused by repositioning the manuscript pages. The feature matching is done using rotationally invariant local descriptors of the Scale-Invariant Feature Transform (SIFT) (Lowe, 2004). Since the computation of the scale-space is computationally expensive and the size of the manuscript pages is similar in different images, the scale-space is not computed in our approach. Thus, each control point detected has the same scale. Since the Difference of Gaussians (DoG) detects too many control points for a registration task the control points are localized using the Harris Corner Detector (Harris & Stephens, 1987). It detects less control points with the same scale parameter  $\sigma$  and is robust against rotational changes too.

The orientation assigned to each control point is computed similar to Lowe's implementation (Lowe, 2004). First the image gradient magnitude  $m(x,y)$  and the orientation  $\theta(x,y)$  are computed for each pixel of the smoothed image  $L(x,y)$ . An orientation histogram with 36 bins corresponding to  $360^\circ$  is created. Each sample added to the histogram is weighted by its gradient magnitude and a Gaussian weight. Afterwards, the histogram is smoothed with a Gaussian kernel. The maximum of the histogram indicates the dominant direction of local gradients.

In order to compute a local descriptor that characterizes each control point the image gradients  $m(x,y)$  and the orientations  $\theta(x,y)$  in a  $16 \times 16$  px window around each control point are considered. The coordinates of the descriptor and the gradient

orientations are rotated relative to the orientation of the control point so that the features are rotationally invariant. Each gradient region is weighted by a Gaussian window of  $\sigma = 8$  so that the descriptor does not change significantly with small changes in the position of the window. The control point descriptor consists of eight  $4 \times 4$  planes where each plane represents the spatial distribution of the gradients for eight different directions. The location of a gradient within the local descriptor depends on the rotated coordinates and its orientation. Each gradient is interpolated to its eight neighbors of the descriptor.

After the features for the reference and the sensed image are computed, they are matched using the nearest-neighbor algorithm. The correspondence of two control points is indicated by the minimal Euclidean distance. Since a control point may exist solely in one of the two images, corresponding control points are rejected if their distance to the nearest neighbor is less than 0.8 times the distance to the second nearest neighbor. Control points which have more than one correspondence are discarded too. Having discarded the control points according to this scheme approximately 200 corresponding control points are left for a  $391 \times 493$  px image.

Since false matches can exist after discarding the previously mentioned control points and a single outlier changes the transformation estimation of the Least Squares Solution dramatically, the RANSAC (Fischler & Bolles, 1981) method is used to discard all remaining outliers. This approach computes the affine transformation using three randomly selected matching points. Having tested all remaining control point pairs, the model is reestimated from the entire set of hypothetical inliers. These steps are repeated until the distances between points and the model meet a given threshold. This method discards in our approach  $\approx 8.3\%$  of previously matched control points. Matched and discarded control points of two manuscript images can be seen in Figure 5.

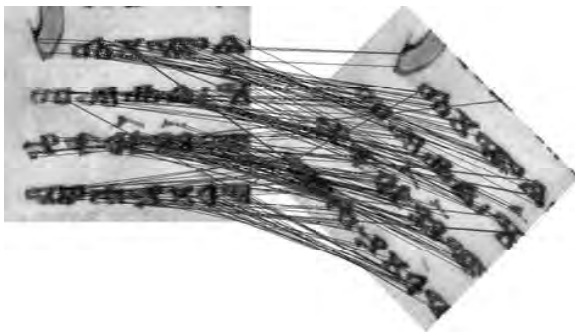


Figure 5: Matched control points. False correspondences are eliminated by means of RANSAC (bold gray lines)

Afterwards, an affine transformation matrix is computed by means of the Least Squares Solution with all remaining corresponding control points. Having aligned both Nikon images coarsely to the reference image using adapted SIFT features and a global affine transformation, a template matching and a subsequent local transformation is performed in order to correct non-rigid distortions caused by changing page curvatures. Due to feature matching and RANSAC it is not possible to spread corresponding control points uniformly across both pages. Therefore the normalized cross correlation is computed at the locations of the previously found control points. Each template contains one character. Having

determined the control points, the parameters for the transformation matrix are computed.

Transformations using polynomials of order  $n$  are defined by at least  $n+1$  parameters, which results in a complex similarity functional that has many local optima. To overcome this problem a local mapping function is applied. The local weighted mean method (Goshtasby, 1988) is a local sensitive interpolation method. It requires at least 6 control points which should be spread uniformly over the entire image. Polynomials are computed by means of the control points. Thus, the transformation of an arbitrary point is computed by the weighted mean of all passing polynomials. Besides, a weighting function is defined which guarantees that solely polynomials near an arbitrary point influence its transformation.

Since the spectral images from the gray level camera are misaligned (minor rotations) template matching combined with an affine transformation is applied. A more detailed explanation of the registration method is presented in Diem et al. (2007).

### 3.3 Image Enhancement

Multispectral image data is often highly correlated, which arises through sensor band overlap and material spectral correlation. A method to reduce highly correlated feature spaces is the Principal Component Analysis (PCA) (Duda et al., 2001). Another method based on PCA is the decorrelation stretch (Gillespie et al., 1986), which enhances the color separation of an image with significant band-band correlation.

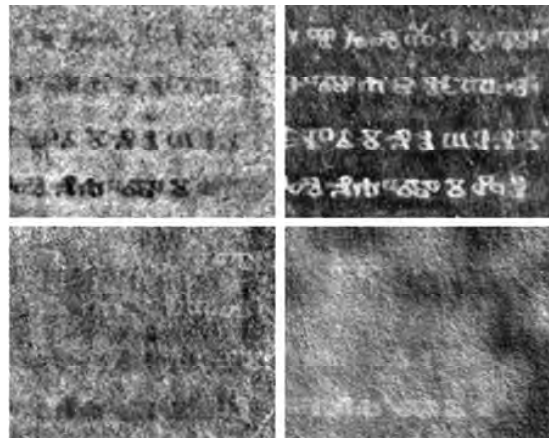


Figure 6: MSC results

The features or the color intensities of each pixel are transformed into the eigenspace of the covariance matrix and stretched to equalize the band variances. Afterwards the stretched eigenspace is transformed back. Another and rather unknown method is the Multivariate Spatial Correlation (MSC), a method for quantifying spatial autocorrelation in multiband data (Wartenberg, 1985). Wartenberg extended a common univariate method of spatial correlation analysis for multivariate data. Warner (1999) took up this method for the analysis of remotely sensed data and showed the robustness in the presence of noise. The spatial correlation methodology can be thought of as a part of a generalized principal component analysis, for details see the Appendix in Wartenberg (Wartenberg, 1985). The resulting images from MSC can be seen in Figure 6. Regarding the input images in Figure 7 it can be seen that the characters especially in the upper left corner and in the middle

of the second and third row are hardly visible. In the second band obtained from the MSC transformation the visibility of the characters is clearly enhanced. The readability of the images is feasible to the philologists who additionally use the context to read the texts.

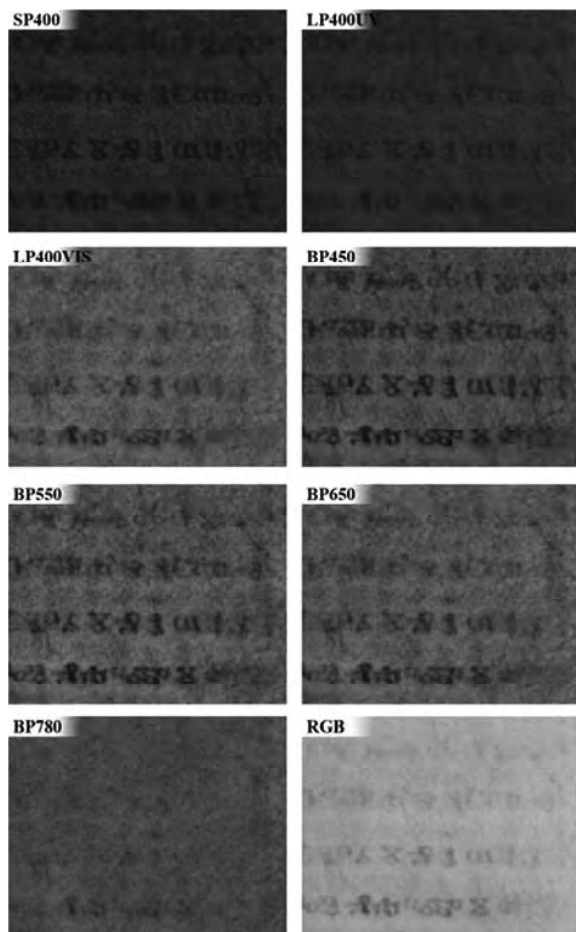


Figure 7: Multispectral images

### 3.4 Stroke analysis

In our approach we combine linguistic and computational methods. The linguistic basis consists of a precise formal (not: functional) and comprehensive catalog of scriptural features, which is not designed only for the Glagolitic, but for any kind of script. This catalog is divided in two superordinate levels of graphetic character description, static and dynamic. The former characterizes the visual shape of the letter, i.e. the state as it is, whereas the latter focuses on the production and consecutiveness of how it was made. For the present purpose only some static features have been considered, and the linguistic definitions have been adapted to the requests of machine handling. This revised list of graphetic attributes is the starting point from which - in the final end - we will single out those features for computer processing that are able to distinctly mark a character in order to facilitate script reconstruction, automatic amendments of (incompletely preserved) letters, and OCR.

Accordingly, we introduce means to dissect each character into analyzable segments for further processing: nodes and strokes.

Nodes are defined as crossings of minimum three line segments, and each line segment or streak coming from a node constitutes a single element and is defined a static stroke. These elements are countable and, thus, give first empirical information on the character. Furthermore, these segments form the basis for the further application of other features, which partly apply not to the character as a whole, but only to an individual segment or several segments of a single character.

Before strokes can be analyzed, a character has to be segmented. This is achieved by combining a thresholding operation for a coarse segmentation and a snake for a contour refinement. Thresholding the image with the method proposed by Gatos et al. (Gatos et al., 2006) results in a binary representation of the character. Since the contours are discretized, a snake (Kass et al., 1988; Xu & Prince, 1997) is applied on them to achieve a smooth contour. The structure of a character is characterized by a skeleton. Skeletons show spurious branches and split-up junctions. Such branches are produced by non-uniformities in the character contours (Gonzales & Woods, 2001), e.g. irregular ink flow. When two strokes cross in a sharp angle, skeletonization methods produce split-up junctions, i.e. two vertices connecting three skeleton segments rather than one vertex connecting four segments. The distance between the two vertices is inversely proportional to the angle at which two strokes cross (Kégl & Krzyzak, 2002). As the algorithm used (Zhang & Suen, 1984) is also subject to these phenomena, the skeleton restructuring algorithm by Kégl et al. (Kégl et al., 2002) has been applied. Hereby the pixels of the skeleton serve as vertices of the graph, and two pixels are connected by an edge if the corresponding pixels are 8-connected. Geometric properties of the graph are used to modify the configuration of vertices. Spurious branches are deleted according to their length and their angle relative to a connected path. Another problem is the merging of split-up junctions; i.e. two junctions connected by a superfluous short path. The length of the superfluous short path depends on the thickness of the strokes and their crossing angle. The sharper the crossing angle, the longer is the connecting path. A threshold depending on these parameters determines whether two junctions belong together or not. The detected split-up junctions are to be merged into one.

This skeleton is used to extract static strokes from characters. The meeting point of the skeleton and the stroke border is the endpoint of the stroke. If there is no meeting point, the skeleton branches are extended until they meet with the stroke border. The direction of this extension is obtained by calculating the average direction of the line segments connecting the skeleton endpoint to its predeceasing neighbors. Figure 8 shows a schematic view of a Glagolitic character with a skeleton. The skeleton is divided into branches, which either go from an endpoint to the nearest junction on the path or consist of paths between junctions. Each part of the character, in which one skeleton branch is embedded, is defined as a static stroke. For calculating graphetic attributes of static strokes the following features are used:

1. Number of nodes per character
2. Number of static strokes per character
3. Number of straight static strokes per character
4. Number of vertical static strokes per character
5. Number of horizontal static strokes per character
6. Number of bent static strokes per character
7. Number of open ends per character
8. Number of loops per character

9. Number of closed elements (number of holes) per character
10. Left-concentrated
11. Right-concentrated
12. Top-concentrated
13. Bottom-concentrated
14. Centered

The first eight of the above features consist of numbers referring directly to the segmentation of static strokes in a character.

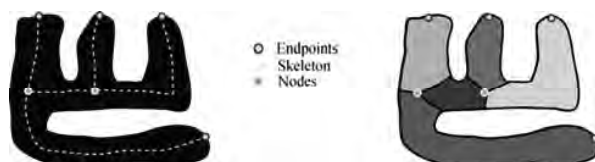


Figure 8: Schematic view of a Glagolitic character. On the left, a segmented character is shown with skeleton, nodes and endpoints. The right side shows the character's static strokes

Figure 8 shows a Glagolitic character with disassembled static strokes. The numbers of the static strokes and nodes are obtained directly from the graph representation of the skeleton. The properties of static strokes include the number of straight, bent, horizontal and vertical strokes. Straight and bent strokes are discriminated by means of the formfactor of a skeleton branch. According to our investigation a stroke is to be considered as straight, if the formfactor is larger than 4, and bent, if the formfactor is smaller. Loops are defined as static strokes where endpoint and starting point meet. The last six attributes are derived from the binary image. Here the image is divided into a  $3 \times 3$  grid. For each row the number of white pixels is determined. If the upper row contains more pixels than the other rows, the gravity of the character is to be seen there; it is top-concentrated. If the lower row contains the maximum amount of white pixels, the character is bottom-concentrated. The same applies to columns, where a character can be either left- or right-concentrated. A character is defined as centered, if the maximum amount of pixels is contained both in the middle row and the middle column of the grid.

### 3.5 Document analysis

In the case of degraded manuscripts (e.g. by mold, humidity, bad storage conditions) the text or parts of it can disappear (e.g. be washed out). The remaining parts of the text can be segmented and the ruling can be extrapolated with the a priori knowledge. Since the ruling defines the position of the text within a page, it can be used for layout analysis and as a basis for the enhancement of the readability. Furthermore, information about the scribe (hand) of the manuscript, its spatiotemporal origin can be gained by analyzing the ruling. Due to the digitization process of ancient manuscripts/documents a rotation angle is introduced to the captured images in relation to the original image axes. Methods concerning e.g. the layout analysis of handwritten historical documents (Bulacu et al., 2007), text line segmentation (Louloudis et al., 2006; Likforman-Sulem et al., 2007; Shi et al., 2005; Kennard & Barrett, 2006) in handwritten documents and automated layout segmentation and classification of printed documents (Cinque et al., 2003) assume that the input image has no skew.

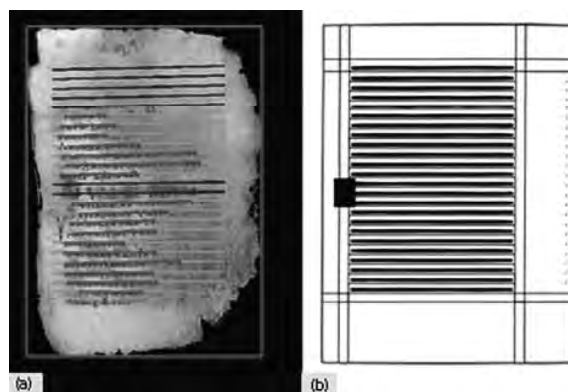


Figure 9: (a) recto side of a folio with estimated ruling (b) a priori knowledge of the ruling scheme Miklas (2000)

Additional “for humans, rotated images are unpleasant for visualisation and introduce extra difficulty in text reading” (Lins & Ávila, 2004) and also Optical Character Recognition (OCR) tools will fail (Mello & Lins, 1999). As a result algorithms for skew estimation and correction are necessary. Methods proposing an algorithm for skew estimation include techniques based on projection profiles (Bagdanov & Kanai, 1997; Su et al., 2007), the Hough transformation (Hinds et al., 1990; Jiang et al., 1996; Amin & Fischer, 2000; Yuan & Tan, 2005; Manjunath Aradhya et al., 2006), morphological based skew estimation (Chen & Haralick, 1994) and methods based on properties of the Fourier transform (Peake & Tan, 1997). Since these algorithms are not or only partly suitable for degraded documents, a skew correction algorithm adapted to the requirements was developed (Kleber & Sablatnig, 2008). The developed method is able to handle documents that contain lines and words with different skews. Hence, for every word/line a weight according to the length of each blob is calculated such that after the correction the dominant direction of the text is horizontally aligned. The type of font is not relevant as long as a clear baseline (Likforman-Sulem et al., 2007) of the text exists. Additional degradations are eliminated through the binarization in the pre-processing step. The algorithm is designed for pages that contain handwritten text without pictures. Degradation of parts of the text are ineffectual as long as determinative parts of the text regarding the skew are still available. After the skew correction, the remaining parts of the text in case of degraded manuscripts can be segmented and the ruling can be extrapolated with the a priori knowledge. The algorithm developed within this project is used to analyze the ruling (information about the scribe (hand) of the manuscript and its spatiotemporal origin can be gained\*) of the Missale Sinaicum (Cod. Sin. slav. 5/N, 11<sup>th</sup> century) (Miklas, 2000) belonging to the classical Old Church Slavonic (OCS) canon. To determine the ruling, the text lines of the folios have to be segmented and an extrapolation of the extracted ruling must be done with the a priori knowledge of the ruling scheme (Miklas, 2000) (see Figure 9 (b)). A typical result of the estimation of the ruling is shown in Figure 9 (a), where the red lines indicate the extracted baselines and the blue and green lines are extrapolated with the a priori knowledge. The developed algorithm has a preprocessing step, which comprises a skew estimation, an adaptive image binarization and a noise removal. After this preprocessing step the text components (words, characters, etc.) are segmented and finally grouped to extract the text lines.

\* See e.g. Leroy for the Greek tradition Leroy (Paris, 1976)

#### 4. CONCLUSIONS

In this paper we presented a project that deals with the investigation of two Glagolitic manuscripts (Codd. Sinaitici slav. 1/N & 5/N), belonging to the classical Old Church Slavonic (OCS) canon. Since almost all of the ca. 80 fol. of the Missal (5/N) are in a deplorable state and cannot be deciphered without special technologies, a multispectral image acquisition system was used (thus providing information that the human eye cannot see). Both the acquisition setup and the nondestructive measurement techniques have been described. For the further development of the images, algorithms have been developed and described for (a) the registration of the images of different spectral bands, (b) the enhancement of the readability of the folios due to the combination of different spectral images, (c) the stroke analysis for Glagolitic characters, and (d) an analysis of the ruling. While image acquisition and enhancement have been treated in computer science and serve for a better readability of latent texts, so far their results had to be deciphered and analyzed by conventional philological methods. Consequently, the computer aided script description and recovery is the major technical innovation in this project. This will open new perspectives for palaeographical and graphemic analyses of alphabetic (phonographic) writing systems, the results of which can also serve as fundamental instruments for textological investigations. Furthermore, collections of palaeographical and graphemic information will enable the solution of dating and localizing problems of manuscripts, scribe schools, and text traditions.

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## SYSTEMISATION OF KNOWLEDGE FOR THE CONSERVATION AND CULTURAL DEVELOPMENT OF PIEDMONT'S MOSAIC HERITAGE.

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**KEY WORDS:** Mosaic heritage, Testimony, Cataloguing resources, Standardisation, Metadata

### ABSTRACT:

Mosaics, in all their possible variants of form, material and location, can and must be recognised within the definition of Architectural Heritage. A further examination also reveals that mosaics are fully included within the definition of Cultural Heritage and, so, constitute part of the CH of a territorial area. In the absence of specific regulations, studies have been carried out in relation to source data and scheduling instruments at national and regional level with a view to devising a schedule model specifically for the mosaic, so that it is no longer regarded as an archaeological finding in its own right, but as a systematic element. These have been compared with other local situations, in Italy and abroad, which need unambiguous parameters for standardisation. These operations pass unavoidably through the identification of parameters, metadata, final users and methods through which the project could be developed in the future. Of no small importance is the diversified input of specific and inter-disciplinary skills, which are necessary for a correct cataloguing of resources; that means determining the obligatory fields and structuring the various headings, devising also appropriate key words. The cataloguing procedure is fundamental in the process for an effective cultural development of Piedmont's mosaic heritage. More precisely, it becomes an element in a structure for multi-level querying of the Territorial Information System, devised in particular for visualising data relating to files on interactive support, but also for a web-GIS configuration.

### 1. GENERAL INTRODUCTION

Mosaics, in all their possible variants of form, material and location, can and must be recognised within the definition of Architectural Heritage, which is defined as "all buildings and structures of conspicuous historical, archaeological, artistic, scientific, social or technical interest, including their fixtures or fittings" (Granada Convention 1985, Art 1 (1)). If this definition is accepted, it follows that the mosaic is included as a fixture or fitting forming part of a building, within the category of architectural heritage. In addition, on further examination, mosaics are fully included within the definition of Cultural Heritage, which means "property and objects of artistic, historical, archaeological and demo-ethno-anthropological interest" (Consolidated Text, point 1, section 1, article 2 (1)) and, as such, constitute part of the Cultural Heritage of a territorial area.

The project for the *Systemisation of knowledge for the conservation and cultural development of Piedmont's mosaic heritage* has been created by an inter-disciplinary research group from Turin Polytechnic\*, which, for various reasons, has

looked at the Piedmont region as a possible field for application. The contribution of a number of sectors has increased the possibilities for analysis and varied the value, nature and quality of the results in a tangible way. In this project it has been sought to exploit the technological capacity of the TIS (Territorial Information System) in order to relate data of varying nature with a geographical representation.

It is our intention for an instrument so designed to be used as an open information system, capable of being continually updated and of guaranteeing a correct process for acquisition, organisation and sharing of documents which will lead to a widening of knowledge, as well as a greater protection and development of a complex phenomenon.

In this context, the Turin Polytechnic research group has sought to identify and promote programmes that focus upon this category of Cultural Heritage, through a systematic development of knowledge for the conservation of this resource, in both the material sense as well as in its value as testimony of a particular period of time. The mosaic is in fact closely linked with the architectural and territorial context in which it is found. Many of the mosaics examined\*\* can be regarded today as true historical works of art, because they are

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\* Group formed for the purpose of studying the Piedmont territorial area which includes various scientific and disciplinary sectors covering representative areas as well as evaluation and development aspects, with the support of the institution to which they belong – headed by the Dean, Prof. Rocco Curto – and involving the collaboration of young academics who take part in the research activities, which are carried out in close contact with teaching staff.

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In this respect, we wish to thank the Doctor of Research, Carlotta Fierro, and Historical Architect and Conservator, Michela Vycpalek.

\*\* In this occasion, we have analyzed all the 65 mosaic's located in Piedmont (Italy) territory (in situ or in museums) in 8 district (Torino, Cuneo, Asti, Alessandria, Vercelli, Novara, Biella, Verbania).

now no longer to be found in the context in which they were designed and made and, even where they have been conserved and are accessible to the public, they are difficult to understand if they are removed from their original setting.

The mosaic is designed to fit in a specific architectural setting as you can see in the relationship between St. Mary Cathedral and its mosaics (following figure).



Figure 1: Mosaic in its context: St. Mary Cathedral's (Asti) mosaic floor representing the myth of Sanson

It follows that the first focus of research has been aimed at analysing the relationship between decoration and architecture, between Cultural Heritage and Architectural Heritage. Without this, it has no context and it therefore loses part of its significance. Having defined the objectives, this programme to understand mosaics in relation to their architectural surroundings envisages the acquisition, monitoring and management of information resources.

We focused on:

- gaining knowledge of state of the art of mosaic's documenting and scheduling;
- instruments for cataloguing Cultural Heritage/Mosaic Heritage (Torino, Piedmont, Italian Regions, Europe);
- Database/DBMS/TIS (from Access to ArcView through the evaluation of Open Source) for the development programmes of sustainable tourism;
- Mosaic as an instrument for the *creation of value*.

These consist of various kinds of material which we decided to organize, initially, through the creation of a database and, subsequently, to link it to the relevant surveying system which enables it to be georeferenced.

## 2. SYSTEMISATION OF KNOWLEDGE OF THE MOSAIC AS A CULTURAL RESOURCE

In order to manage complex information systems, documentary data and pictures, it is important to choose an appropriate archive instrument which is flexible and capable not only of collecting information but above all of monitoring it and making it accessible. The disorganised, casual accumulation of data, aimed at amassing the largest quantity of information, becomes an end in itself. When data and information are stratified without structuring the acquisition according to unambiguous parameters and according to closed fields of compilation – which limit the subjectivity of the compiler in order to encourage the objectivity of the analysis – there is a risk of losing logical links connecting together the various

pieces of information. It follows that the most complex aspect of the work of cataloguing is in the actual planning of ways of accessing to the information, since information technology makes it possible to memorise and consult quantities of data in logical-associative ways. Today it is necessary to design instruments that are capable of adapting themselves to changes in cognitive and communication paths, in other words through the use of dynamic cataloguing.

The structuring of the databases lies at the very foundation of the plan for an information system for the promotion of the Piedmont area, through the creation of an instrument for the definition of thematic paths. In specific terms, a database has been designed to catalogue mosaics in the Piedmont region in the various periods, seeking to link them to the territorial area and above all to the architectural contexts in which they were created. In some cases fragments, which are not conserved *in situ* any more, have come to light and are now displayed in surrounding far away from their original site. The database has been organised, starting from the analysis of existing forms of cataloguing for the mosaic, and it has been compared with the most modern information systems in Piedmont.

The cataloguing, management and development of this resource can therefore become of growing importance at regional level and lead to the adoption of new models and instruments that are capable of satisfying the requirements of flexibility and of integrating information of varying origin and nature. The phase for acquiring knowledge about museum exhibits covers the acquisition, monitoring and management of information resources, which consist of materials of varying types. Studies of source data and scheduling instruments at a national (ICCD) and regional (Guarini Project, source data of the Piedmont Cultural Monitoring Unit and the Regional Tourism Monitoring Unit) level have been carried out in order to devise a schedule model specific for mosaics, so that they are no longer regarded as archaeological findings but a systematic element, in absence of specific regulations. These have been compared with other local situations, in Italy and abroad, where unambiguous parameters are needed for the purposes of standardisation.

Below is a description, with a SWOT analysis – an acronym indicating the Strengths, Weaknesses, Opportunities and Threats – in relation to the systemisation of knowledge for the development of Piedmont's mosaic heritage.

### 2.1 Instruments for Cataloguing Cultural Heritage/Mosaic Heritage in Italy

Analysing the operation of the ICCD\*, the *Istituto Centrale per il Catalogo e la Documentazione italiano* – an institution set up in 1959 in order to promote and coordinate cataloguing and documentation activity, as well as setting up and managing the general cataloguing system for cultural resources of archaeological, historical, artistic and environmental interest – it is immediately apparent that there is no specific cataloguing system for the mosaic. Mosaics are included in the category of archaeological findings and such a choice is clearly limiting when it comes to mosaics that do not come from archaeological excavations.

The need for an articulated organisation of information, taking into account the descriptive and interpretative nature of the architectural, environmental, archaeological, historical and

\* For further information: <http://www.iccd.beniculturali.it>



artistic information, has been examined by the ICCD, drawing attention to a rigorous structure of information contained in descriptive files and aiming towards a standardisation of them, so that they are compatible with the various types of file, in order that it is possible, through automation, to reconstruct the connective framework which links the various works to the relevant architectural and territorial contexts. First of all the ICCD has sought to provide a conceptual definition of the mosaic under examination as a "simple object", "composite object" or "group of objects" and to propose specific compilation procedures for each of these. Subsequently, for the structuring of data, it has arranged the information into elementary units which are independent from hardware and software systems. After this, the information is divided up into fields, sometimes grouped into paragraphs, which can then be structured into sub-fields.

Afterwards, it has been analysed according to the type of data and logical relationships between the data that can be acquired in the various existing file models, highlighting the possible ways of implementation.

Mosaics are included in the category of objects to be catalogued within the sector of Archaeological Heritage in the sub-category of Moveable Resources, and therefore mosaics that are still *in situ* (being Property Resources) would remain excluded from the "RA" –*reperto archeologico* (archaeological find)– file, even if it has been proposed to create a *RA-M file* which relates exclusively and specifically to Mosaics; vocabularies have been compiled in relation to the mosaic, the non-figurative mosaic and the mosaic floor.

For completeness, an examination is made of the "OA" –*opera d'arte* (work of art)– file and the "A" –*architettura* (architecture)– file in order to obtain a direct relationship with architectural contexts in which the mosaics are created\*.

**2.1.1 RA file.** File devised by the ICCD for the cataloguing of Archaeological Resources: it contains a whole series of specific information that connects this type of asset with the place in which it is found and the characteristics of the excavation. In relation to the purpose of the research, it is inappropriate for documentation of mosaics that have not come to light during archaeological excavations. The file is subdivided into 22 paragraphs that can include structured (and non-structured) fields, with the possibility of adding further sub-fields that are recognisable within the same framework with a code for each heading.

From a SWOT evaluation, the RA file shows its particular points of strength insofar as being complete and clear for Archaeological Finds, standardised and therefore accessible throughout the whole national territory; its weaknesses are the clear lack of flexibility in the description of more detailed mosaics – not originating from archaeological excavations – and difficulty in compilation, despite the use of key words, for use in the management of the rich heritage of mosaics in Piedmont.

\* This analysis was carried out following the specific compilation regulations (for the RA file, the OA file and the A file) to be found at: <http://80.205.162.235/Catalogazione/standard-catalografici/normative/scheda-ra; scheda-oa; scheda-a>

**2.1.2 OA file.** File created by the ICCD for cataloguing Works of Art, subdivided into 21 paragraphs for each of which there can be structured (and non-structured) fields, with the possibility of adding further sub-fields that are recognisable within the same framework, with a code for each heading.

From a SWOT evaluation, the OA file demonstrates various points of strength in being exhaustive and technical for works of art, with specific key words for mosaic resources, suitable for compilation by the authorities responsible for managing the territory; its weakness is to be fairly inflexible in relation to the specific characteristics of mosaic resources and difficult for the general, non-specialist user to compile, despite the provision of key words; as a result it is not suitable for managing the rich heritage of mosaics in Piedmont.

**2.1.3 A file.** File created by the ICCD for cataloguing Architectural Monuments. The A File is subdivided into 32 paragraphs, each of which can include structured (and non-structured) fields, with the possibility of adding further sub-fields that are recognisable within the same framework with a code for each heading. A further 16 are introduced, which give a more specific description of the architectural monument.

From a SWOT evaluation, the A file demonstrates various points of strength in providing an exhaustive technical description of the architectural resource, which is suitable for compilation by authorities responsible for administering the territorial area; its weaknesses includes a clear unsuitability in managing data relating to mosaics except for the description in the relevant architectural context; it is also difficult for the general, non-specialist user to compile, despite the provision of key words; as a result it is not suitable for managing the rich heritage of mosaics in Piedmont.

## 2.2 Instruments for Cataloguing Cultural Heritage/Mosaic Heritage in Piedmont

After an examination of the cataloguing directives and standards drawn up at national level by the ICCD, the next step relates to research projects at regional level carried out, throughout Italy for the management of cultural resources and, where they exist, relating directly to mosaics.

This began, naturally, with a consideration of the situation in Piedmont, where no cataloguing in relation to mosaics has been carried out up until now. The study was then widened to cover those Italian regions that have created well-established databases, specifically for the cataloguing of mosaics.

**2.2.1 Guarini Project.** Even though there have never been any cataloguing activities relating exclusively to mosaics, projects are currently being carried out for the archiving and monitoring of resources over the entire regional area, in its overall form, including archive and library resources and cultural resources in the widest sense of the word.

In this respect, first of all, there was an examination of the Guarini Project\*\*, which was set up by Piedmont Regional Authority in the mid-1990's and consisted of the Guarini Cultural Resources, Guarini Archives and Guarini Library Resources. Since 1994, Guarini software has been the standard cataloguing instrument in the Piedmont area and CSI-Piemonte

\*\* For further information: <http://www.regione.piemonte.it/cultura/guarinipat/index.htm>

Information Consortium has the task of setting up the software and distributing the procedure among the authorities responsible, providing also the necessary assistance. In 2000, the *Guarini Venaria Reale* software was created as a result of the need to catalogue the documents produced during study and monitoring programmes for the restoration of the Savoy Royal Palace at Venaria Reale.

The standards used are reminiscent of those of the ICCD, with variations relating to the models of the specific files for each type of Resource.

The starting point was based upon the work of the ISAD\*\*\* (General International Standard Archival Description), standards drawn up by the ICA (International Council on Archives), adopted by the Committee for Descriptive Standards (Stockholm, 19-22 September 1999); although modifications were made in relation to the hierarchy of information and the inclusion of new fields that provided a greater amount of details.

Of fundamental importance was the association of one or more images to the catalogue record and the georeferencing of data relating to the territorial area. During the phase of access to the catalogue system it is necessary for users to provide information of identity and there are various levels of access: supervisor (use of all functions), reader (consultation and printing of data only), file holder (access to its own files only) and officer (non-default user who cannot carry out maintenance of external files).

The final objectives are the development of Piedmont cultural heritage, collaboration between authorities and institutions, the diffusion of information acquired among citizens and researchers and, naturally, the safeguarding and promotion of the catalogued resources.

A SWOT evaluation of the Guarini software indicates, among its points of strength, that it has been created specially for the cataloguing of Piedmont cultural heritage, but this now also represents a point of weakness, since, although it is shared by the scientific community, its application cannot be shared at national level. It also presents various difficulties when it comes to compilation by a general, non-specialist user.

**2.2.2 OCP - Observatory Cultural Piedmont.** There was also a study of the census of Museums and Cultural Resources in Piedmont carried out by the Piedmont Regional Authority in collaboration with *Fondazione Fitzcarraldo* and *IRES* (the Economic and Social Research Institute), operating at national level but in this case relating to the part concerning Piedmont. This promotes surveys in social, economic and territorial fields, with functions of support for the programming action of the Piedmont Regional Authority and other institutions and local authorities at regional level.

The purpose of the survey was the creation of a database with detailed information on many different aspects of museums and cultural resources, which is accessible to the public in controlled form, even though free of charge. In particular, surveys were carried out on institutions that satisfy the definition of museum as laid down by ICOM (International Council of Museums), drawing up a list, sub-divided according

to province and category, of the cultural institutions involved in the survey, which include several places where mosaics are conserved\*.

It should be pointed out that attention was given during the survey phase to the relationship between the resources and the territorial area, and to the possibility of visiting and viewing the collections. Among the cataloguing criteria there is an alphanumerical code consisting of the initial of the province of origin and a progressive number so as to provide a faster way of searching and compiling the files.

A SWOT evaluation of the Census of Museums and Cultural Resources shows, among points of strength, that it is fully shared with the authorities responsible for administering the territorial area; the weakness is in not offering the possibility of access to Metadata but only to statistical data and the processing of resources subdivided by province.

### 2.3 Instruments for Cataloguing Cultural Heritage/Mosaic Heritage in other Italian Regions

The Emilia Romagna and Veneto Regional Authorities have tackled the problem of computerised management of mosaics with local projects aimed at the cataloguing of territorial areas and their mosaic resources.

From the examination of these types of file, various limitations emerged in relation to their adaptability for cataloguing Piedmont mosaics, especially with regard to the purposes and the different users involved in the projects currently being operated in the Emilia Romagna and Veneto Regions.

**2.3.1 CIDM - International Documentation Centre for the Mosaic of Ravenna (Emilia Romagna Region).** In 2003, the CIDM was created as part of the MAR (Ravenna City Art Museum) in order to promote research, study and cultural development of mosaics in the city which symbolises the culture of the mosaic\*\*. It has two distinct databases: one for the mosaic (ancient and contemporary) and one dedicated to contemporary mosaic workers (which is a list of companies, firms and private mosaic makers operating in the Ravenna area).

The research carried out by the CIDM has sought to produce a catalogue file that was compatible with ministerial surveying standards relating to cultural resources, which at the same time was accessible by internet to everyone, even though there were various different kinds of user.

The work led to the production of documentation and to the promotion of mosaic work, with the creation of a single catalogue file, structured in the same way for ancient as well as for modern mosaics, in which only the appropriate fields are completed according to type.

In relation to files' structure the starting point was the OA (works of art) files of the ICCD with additional data derived from other standards relating to files for RA (archaeological resources), OCA (contemporary works of art), A (architecture) and (CA) archaeological sites. The files are brought together in

\*\*\* For further information: [http://www.anai.org/attivita/N\\_isad/Isad\\_main.htm](http://www.anai.org/attivita/N_isad/Isad_main.htm)

\* For further information: <http://www.ocp.piemonte.it/>; <http://www.fitzcarraldo.it/>; <http://www.ires.it/>

\*\* For further information: <http://www.mosaicocidm.it/index.do>

the database and can be consulted on line. There is a limitation to this system of filing, due to the fact that there is no opportunity for an overall vision of the complete catalogue file for all headings because only the compiled fields are visible.

From a SWOT evaluation, the CIDM project demonstrates its points of strength in being suitable for the management of mosaics from various periods of time, with a specific but sharable language that is open to the general user; its weaknesses are in not offering points of contact with the architectural context in which the work was located and/or relocated.

**2.3.2 TESS – Padova (Veneto Region).** The second project examined has been created by the Department of Archaeology at Padua University for cataloguing mosaics from the Roman period in the Veneto Region\*\*\*.

The TESS project, from these initial objectives, was extended to mosaics in Liguria, Tuscany, Emilia Romagna and Friuli Venezia Giulia, and created a database that would meet the requirements of accessibility and user-friendliness, as well as completeness of information, to offer a cataloguing instrument that would assist in protection and also in the study of mosaics on the basis of their decorative forms, distribution, craftsmen and local ways.

The project was built upon a study of research carried out in France in the middle of the last century with the first attempts to catalogue ancient mosaics. The file has a hierarchical structure arranged on six levels, from general to specific.

The TESS file is devised to provide a synthesis between the requirements for an historical and artistic reconstruction in relation to the mosaic and the administrative requirements of protecting and conserving the cultural heritage. All of this is reflected in the study of classes of user with a protected, hierarchical system of access according to the person wishing to gain entry, in order to avoid interference and undesired access to information.

From a SWOT evaluation, the TESS project demonstrates, among its points of strength, an inclusion of the relationship between mosaic and architectural context, and a comprehensive description with specific language; its weaknesses include the fact that its objective is to manage ancient mosaic pavements and this means that the Padua model is poorly adaptable to cataloguing a broader time period, and also that the language is too technical and difficult to be shared with the general user.

#### 2.4 Comparison with European Cataloguing Instruments of Cultural Heritage/Mosaic Heritage

In France, the *Ministère d'Etat, chargé des Affaires Culturelles* was created in 1959, thanks to the work of André Malraux. After various changes, it became the present *Ministère de la Culture et de la Communication*\*. The cataloguing activities led to the creation of the *Inventaire des Monuments et Richesses Artistiques de la France* which, although it includes very many databases, does not include any specific cataloguing system for French mosaics.

In Great Britain, the MDA\*\* (Museum Documentation Association) is the central body which is equivalent to the Italian *Istituto per il Catalogo e la Documentazione* and the French *Inventaire* described above. The MDA set up a series of cataloguing models some time ago under the control of the *Royal Commission on the Historical Monuments of England* which has also produced publications in the form of manuals for a correct and unambiguous form of compilation; but here, once again, there is no specific cataloguing system for mosaics.

### 3. MOSAIC HERITAGE AS AN INSTRUMENT FOR THE CREATION OF VALUE

The mosaic resources cataloguing project also has the purpose of enabling the authorities responsible for administering the Piedmont cultural heritage to carry out protection and cultural development activities. These users (Superintendent and regional and municipal offices) can broaden such headings and operate the system, thanks also to the widespread and specific knowledge of the territorial area.

It is appropriate to seek to protect these resources on the basis of the current legislation, to create value not only in relation to the object itself but also for the architectural and territorial context, and also to define projects for promotion and conservation that are sustainable over time, planning public or private initiatives that lead to investment in the territorial area.

What has emerged from the state of the art with regard to cataloguing instruments for mosaic resources is the lack of a specific cataloguing system for mosaics. This has been confirmed by direct contact with local institutions.

#### 3.1 BM file project

The catalogue file proposed for the Piedmont mosaics, BM file (*Bene Mosaico*), for the purposes described above, has therefore been devised as a single file subdivided into various thematic sections for greater ease of research, along with a bibliographical entry that is similarly structured.

Innovative fields in this specific mosaic cataloguing project are in *italic* font in order to give an easier understanding. These fields are new relatively to all the file cards analyzed before.

The fields include:

- LR – PLACE OF DISCOVERY  
*ID Finding place, Country, Region, District, Finding district ISTAT Code, Finding municipality, Finding actual place, Finding place ISTAT Code, Place at the time of finding, Finding street code, Finding street number, IGM map.*
- LC – PLACE OF CONSERVATION  
*ID Conservation place, Conservation in situ ((Y/N), Country, Region, District of conservation place, Conservation district ISTAT Code, Conservation municipality, Conservation actual place, Conservation place ISTAT Code, Place at the time of finding, Conservation street code, Conservation street number, IGM map.*
- CA – ARCHITECTURAL CONTEXT  
*ID Architectural context, Architectural context typology, Actual name, Execution age, Specificity execution age, Bibliography for the age, Architectural plan with room*

\*\*\* For further information: <http://www.archeologia.unipd.it>

\* For further information: <http://www.culture.gouv.fr/culture/inventaire/patrimoine.html>

\*\* For further information: <http://www.mda.org.uk.html>

indication, *Architectural plan caption*, Room typology, *Iconographic image*, Room form and dimension

- O – OBJECT

*ID Object*, Illustrating image, *Image caption*, Object Typology, Execution age, *Bibliography for age and authors*, Dimension, Execution method, Materials, Coloration form, Decoration typology, Brief description, Description, Bibliography, Geometric decoration (Y/N), Geometric decoration theme, Geometric decoration modular repetition, *Geometric decoration description*, *Geometric decoration image* (following Figure 2), *Geometric decoration image caption*, Vegetable decoration (Y/N), Vegetable decoration theme, Vegetable decoration modular repetition, *Vegetable decoration description*, *Vegetable decoration image*, *Vegetable decoration image caption*, Figurative decoration (Y/N), Generic subject matter, Relevant category, Theme, Specific subject, *Figurative decoration description*, *Figurative decoration image* (following Figure 3), *Figurative decoration image caption*, Inscription (Y/N), Inscription position on mosaic, Language, Text transcription, *Explanation/Traduction text*, *Bibliography for the inscription*, *Inscription image*, *Inscription image caption*, *Existing schedule file for the mosaic or its context* (Y/N), *Schedule file typology*, *Compiling authority*, *Schedule file number*.

- R – RESTORATION

*ID Restoration*, Restoration actions (Y/N), *Restoration act chronology*, *Bibliography for the chronology*.

- V – CULTURAL DEVELOPMENT

*ID Development*, Reference to Local Tourist Agencies, Possibility to view (Y/N), *Explanation of unvisibility*, Existing road network, Existing railway network, Existing public transport network, WebGis transport link, Place of conservation typology, Place of mosaic exhibition, Possibility to visit (Y/N), Visit condition, Access condition, Contact, Website, Inclusion in existing circuits (Y/N), Promoting authority, Circuit name, Information availability, Total tourist movements: arrives, Total Tourist movements: presences, Italian tourist movements: arrives, Italian tourist movements: presences, Foreign tourist movements: arrives, Foreign tourist movements: presences, Tourists medium stay, Total number of accomodation, Cultural heritage presence, Cultural heritage typology, Total number of cultural heritage in the area, Number of visitors.



Figure 2: The floor fragmentation, coming from Tortona (AL), shows geometric decoration with modular repetition of elements as teeth saw, two top twists, lozenges, Solomon knot



Figure 3: Figurate fragmentation part of Casale M.to (AL) ancient Cathedral with religious theme showing Abram fighting four Kings

**3.1.1 From Access to ArcView through the evaluation of Open Source.** These sections have been organised on Access with related databases, with a primary key that provides a clear unambiguous identification of the mosaic.

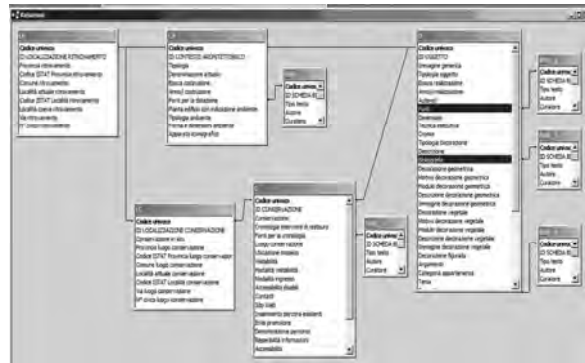


Figure 4: ACCESS relational form

The creation of a database that is integrated into Access has made it possible to manage data and information of different kinds through a conceptual project which includes standard as well as newly devised data fields and a logical project according to a multi-profile arrangement, in other words for a multiplicity of potential users at regional level.

In order to share this info system the “Open Source” system should be used. In this contest we prefer to split information on different levels using easily accessible programs. These programs are already working in public structures that use Office DBMS info systems.

### 3.2 Instruments for the creation of value

With a view to rediscovering mosaics not only as objects to be preserved and promoted, but at the same time as factors that give special value to the territorial area, it has been necessary to carry out an initial examination of their territorial distribution in order to identify certain thematic considerations.

Once that all useful information have been collected, and that BM file has been proposed for the management of the mosaic resources in order to promote the cultural development of Piedmont, the following phase is to analyze how the project could be developed with a dialogue with the responsible authorities and to understand how to promote the necessary

involvement and interaction between the various specific authorities in order to produce a correct cataloguing system for the provision of information, protection and cultural development of the resources and the territorial area itself.

After having recognised the cultural context, identified the relevant standards, defined the rules for compiling the files, the principle of sharing and interaction form the basis for the multi-language portals that are to be set up. Their cultural importance and value is clear, given the possibility of sharing information between institutions, administrations and users. They consequently demonstrate the need for a Territorial Data Infrastructure as a fundamental factor in managing cultural resources.

This objective provides the creation of an information system in which the information relating to the mosaics goes together with the information relating to the territorial contexts, in the form of georeferenced interactive thematic maps. This information architecture makes it possible to make individual queries, according to the area of interest, as well as overlay operations on all information relating to each individual point which is clearly and unambiguously positioned.

In a subsequent phase, the interdisciplinary research group arranged cultural development programmes for the mosaic resources in the specific context of the Piedmont region, through the setting up and visualisation of thematic maps which were created *ex novo*.

### 3.2.1 Tourist circuits in Piedmont Region: state of the art.

Given that the purpose is to create itineraries based on the territorial distribution of the mosaics, it was of fundamental importance to consider this option in relation to the tourist circuits already organised and promoted by the Piedmont Regional Authority, i.e. the Piemonte Emozioni\* and Piemonte Card initiatives which are season tickets for Turin and Piedmont museums. Analysing these programmes, various points of contact emerged between the main territorial attractions and the presence of mosaics.

In order to carry out a reciprocal promotion of the central attractions and the mosaic resources, a field entitled "description of itinerary" was inserted into each itinerary, providing the possibility of viewing in detail some of the files illustrating the individual attractions over the territorial area in relation to the accommodation available.

The twofold nature of the Territorial Information System – of planning and managing information fixed to a mapping support specifically created by the Piedmont Region SITAD\* – makes it possible to pass from the cataloguing and archive phase for each resource to the programming of data into the georeferenced support, with the possibility of querying the system in relation to the management of cultural development aspects.

**3.2.2 Profile of final users.** Four different final users have been identified: researchers and academics interested in

mosaics; tourists and enthusiasts interested in mosaics; researchers, academics and experts in the management and development of the territorial area; and finally the 'administrator'. In specific terms, the first of these categories includes those people who have a scientific approach to the objects, who are interested in a whole series of headings which provide information that is as comprehensive and correct as possible about the architectural context and the circumstances of the discovery, the date of the architecture and of the mosaic itself, an analysis of the decorations and techniques used, and indications about any restoration or other operations. This first level of analysis (for the subsequent choice of fields to be included in the catalogue file) has made it necessary to look at the specific disciplines for understanding the history, technique and iconography of the mosaics which only an historian, restorer or expert can have. From this point of view it is of fundamental importance to draw up a suitable and accurate list of key words to which the compiler must refer in programming the data under specific headings. Tourists and mosaic enthusiasts, on the other hand, could be users with different needs, who wish to learn more about Piedmont mosaics and visit the sites. This has led to the inclusion of additional headings relating to the cultural development of the resource, which are useful to the tourist in providing information about locations, methods of access, viewing, possibility of visits, as well as a whole series of information relating to logistics and practical matters (opening hours, booking, etc.). In this respect, the local ATL (Local Tourist Agencies) have been of fundamental importance.

The third category of user relates to researchers, academics and experts who are concerned with the administration and cultural development of the territorial area, since the creation of itineraries presupposes the inclusion of headings relating to the problems of administration (particular codes, information about access and the possibility of visits), with additional information about the potential of the area (tourism and cultural interest). This consideration involves an analysis of tourist figures (subdivided according to the ATL) and cultural attractions already available in a given area. Interdisciplinary skills – which are fundamental to cultural development – provide such fields as a result of the activities of data entry, monitoring and figures obtained. The structure of the database provides tourists with information regarding the real possibilities of access to mosaic resources: continual updating makes it possible a periodical and systematic support in the programming of cultural attractions and means of access to them, in the same way as the heading for restoration operations.

## 4. TOWARDS PROGRAMMES FOR THE DEVELOPMENT OF THE PIEDMONT MOSAIC HERITAGE

The Territorial Information System case study of mosaic resources in Piedmont is directed towards objectives which relate to an understanding of the mosaics themselves and the factors that describe them, as well as their territorial distribution and their protection and cultural development in terms of access etc., in line with their possibilities of attracting tourism. Such actions can create value for the mosaic resources through information, territorial promotion, etc. The mosaic therefore becomes an asset to be promoted and, at the same time, appreciated for the workmanship contained within it.

\* For further information: <http://www.piemonte-emozioni.it/>

\* SITAD, Sistema Informativo Territoriale Diffuso (Cross-territory Information System), for further information: <http://www.regione.piemonte.it/sit/argomenti/pianifica/sit/sitad.htm>, <http://www.sistemapiemonte.it/serviziositad/index.shtml>

The project makes it possible to carry out multilevel queries of the system, with a variety of different scenarios and the possibility of integrating different data sources relating to specific objectives, such as itineraries by groups of experts to visit mosaics that have a particular common characteristic or, alternatively, routes identified on the map, following pre-selected routes and/or according to accessibility. The creation of pre-arranged itineraries can assist local development and produce effects upon the social and economic system, promoting particular areas only in relation to the infrastructures available.

The Territorial Information System, organised in this way, developed using the ESRI, makes it possible to access a set of possible choices, put together on the basis of subjective relationships or of objective parameters and regulations, and therefore offering the possibility of selecting from a 'fixed menu' or an 'a la carte menu'. The data, with its twofold alphanumerical and geographical properties, is viewed directly by the programme in separate layers, which are different in nature, for example covering Region, Province and Municipal areas. In particular, two new layers have been included, entitled "mosaics" and "mosaic discoveries", which provide specific information identifying mosaics that can be actually visited in the territorial area and places where mosaics have been discovered and are not visitable any more.

In order to indicate the distribution of mosaics across the territorial area, they have been classified according to the state in which they are to be found (mosaics conserved in situ, re-mounted, temporarily not viewable, no longer viewable). The final result is to have the 'Mosaics' layer sub-divided into two sub-fields (mosaics conserved in situ and re-mounted mosaics) and the 'Mosaic Discoveries' layer into three parts (mosaics re-mounted (meaning on their original site), mosaics temporarily not viewable and mosaics no longer viewable).

#### 4.1 A structure for multi-level query

With regard to the predefined set of queries to the system, a first level of most elementary research consists of consulting the data base of mosaic resources by district (Province, Local Tourist Agencies, etc.). By using this type of query, it is possible to cross-relate and georeference various pieces of information regarding one or more aspects concerning the aesthetic or artistic value of the mosaics.

A second level of query relates to the presence of mosaics within the municipal area, interrelated with the option of visiting other similar mosaics. It is possible to carry out a cross-related analysis, for example, between Roman and Medieval mosaics and the presence of cultural resources defined as historical and archaeological ones.

A third level of consultation offers the possibility of inter-relating routes already devised by others *ex-novo*: in this case, it is necessary to choose on the basis of the authority offering the itinerary (*Piemonte Emozioni, Piemonte Card*) and on the basis of the mosaics being researched (e.g. Roman mosaics) or on the basis of their location within the territorial area (provincial, local tourist agency, regional etc.).

A fourth level, on the other hand, focuses attention on the question of accommodation in municipal areas where the mosaics are, because someone following such itineraries might be interested in finding out about available accommodations.

This querying method is relevant from the point of view of Regional Tourist Monitoring Unit statistics.

Finally, a fifth level, aimed more at those involved in tourism promotion and territorial development, rather than direct users of the programme, seeks to correlate the places in which mosaics are to be found with tourist movements.

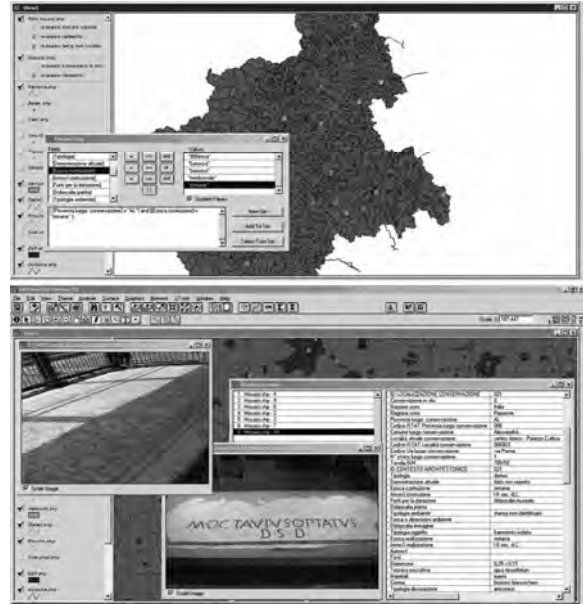


Figure 5: Example of first level of query

These five possibilities have the purpose of giving possible examples for navigating the complex system of data, which includes geographical information, information on the location of the sites where the mosaics were discovered and where they are conserved, the characteristics of the mosaic itself, in all of its cultural and decorative aspects, as well as information relating to access to the mosaic and other cultural and tourist attractions in the area where it is located.

## 5. CONCLUSIONS

The project has sought to establish methods for monitoring and administering Piedmont's mosaic heritage; it constitutes a significant factor in the cultural development of the "territorial system" in which it is located, thanks to the creation of conceptual and logical models which have been described. In this sense, these models have been devised in close relationship and involvement with the initiatives carried out over the territorial area and with a view to their use by a broad range of users. These itineraries must be planned by authorities who possess knowledge of the territory in which they operate, as well as technical skills, and also the ability to use the GIS instrument or web GIS.

Future developments of the system will involve the competent authorities, in order to include their policies in terms of promotion of resources and cultural development of the regional heritage, with a view to creating cultural circuits in which mosaics are to be found. A further outcome relates to a possible networking of the Gis system by transforming it into a WebGis project, thanks to which the general user can have

access to data, creating personal navigation routes for information and viewing.

This does not exclude the possibility of further developments and further possibilities for navigation and querying, but it has been sought to provide a picture of what is now the principal potential offered by the Territorial Information System, from a "simple" cataloguing instrument to a sophisticated support system for programming strategies for territorial resources.

This concept is relevant above all with regard to the cultural development section, in which the information, provided in thematic form, can offer vital support in policies for developing the territorial heritage.

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## ENRICH: AN ECONTENTPLUS PROJECT FOR CREATION OF A EUROPEAN DIGITAL LIBRARY OF MANUSCRIPTS

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**KEY WORDS:** Digitized Manuscripts, Digital Library, Intersystem Communication, Content Aggregation

### ABSTRACT:

ENRICH (<http://enrich.manuscriptorium.com>) will aggregate the digital content concerning manuscripts and partly rare old printed books from a number of various European institutions with the aim to provide seamless access to distributed resources. The ENRICH platform is the Czech Manuscriptorium Digital Library (<http://www.manuscriptorium.eu>), which already presented data from 47 institutions at the beginning of the project. Manuscriptorium will not only harvest metadata via OAI with references to data files in remote image databanks, but it will also support the newcomers by a number of tools needed for authoring and easy contribution. It will enable the researchers to work with analytical digital objects in order to create their own documents across repositories and it will provide multilingual services. A lot of attention will be paid to handling of various description formats incl. the bridging of TEI P.4 and P.5 versions and MARC-based resources. The project has 18 direct partners and a substantial number of associated partners from many European countries, but also from Korea and Kazakhstan. In the end of 2009, more than five million digitized pages will be seamlessly accessible from ca. 60 or more institutions. The project is coordinated by the National Library of the Czech Republic in the period from December 2007 to November 2009.

### 1. INTRODUCTION

The Czech National Library in Prague and the AiP Beroun Comp. Ltd. have been working on digitization of manuscripts and rare old printed books since 1992. Their activity started under the umbrella of the UNESCO Memory of the World programme for which they produced several pilot projects, incl. CDs with fully digitized manuscripts or two editions of know-how CD that summarized the technological approaches to be used for this purpose (Knoll A.; Psohlavec S., 1997 and 1999). Most UNESCO-related activities took place in 1990s, while in parallel the Czech partners started with routine production in digitization. Since 2000 they have been able to involve also other Czech institutions into the digitization programme whose today's name is Memoria.

In 2002, they launched a digital library called Manuscriptorium (<http://www.manuscriptorium.eu>) that managed to provide access to the data of 47 institutions (from which 11 were from outside of the Czech Republic) through the year 2007, i.e. before the beginning of the ENRICH project. The experience acquired during aggregation of data from various types of institutions and the fact that Manuscriptorium qualified itself to be the largest manuscript digital library in Europe led in 2006 to the application in the European eContentPlus programme with a project, called ENRICH, that promised to concentrate the efforts of 18 European institutions on enhancement of content and functionalities of Manuscriptorium. This idea was also supported by a number of other institutions which considered their involvement as associated partners. ENRICH has addressed the national libraries that digitize manuscripts (Manžuch, Z., Knoll, A., 2006), and also other content holders, and relevant technological partners.

The reason to concentrate on manuscripts and very rare documents is that their users prefer special digital research

environments that meet more specific requirements rather than general portals or general digital libraries in spite of their possible personalization. It is felt that seamless data aggregation in this area brings an important added value to all the individual digital collections, while on the other hand such an integrating digital library can easier bring a part of the contained information to larger portals, such as TEL or Europeana, also from small institutions that can be hardly individually accessible due to many factors, including their problems to go on-line so fast as they can with Manuscriptorium.

### 2. THE PRINCIPLES OF MANUSCRIPTORIUM

#### 2.1 Compound Document

When the routine digitization production started in 1996, we looked for having a more generalized solution for our work. At that time or a bit later, there was a lot of discussion, mostly in U. S. (Coleman, J., Willis, D., 1997), about the suitability of SGML for binding the descriptive textual information with digital representation(s) of the original documents.

We needed desperately the relative independence of our data and their structuring of concrete presentation platforms that, unfortunately, was an approach mostly common for the CD-ROM editions of the time. We preferred to have one presentation tool that would be able to work on data based on an open and highly readable platform. That platform was SGML, but it was not generally used for this purpose at that time. We needed to bind the SGML text with the external binary data and still to have easy access to the complex document that was (and still is) called compound document, i.e. a highly structured hybrid set of metadata and binary data (mostly images representing various parts of the original document).



The SGML approach was possible, but we also needed an easily applicable presentation which could be created dynamically from the SGML mark-up. In other words, we needed something that was much later defined as XML. Of course, another necessary reason for this was our feeling that most probably a generally accepted presentation tool was going to be an Internet browser. However, at that time the browsers were able to manage only the basic HTML formatting of appropriately marked-up elements.

Knowing this, we needed to combine this formal mark-up with content oriented mark-up that was possible in SGML. The first idea was to introduce directly our own elements into HTML that was really done in two versions and published (Knoll A., Psohlavec S., 1997; Knoll A., Psohlavec S., 1999) as a DOBM Document Type Definition, a kind of hybrid of HTML and necessary types of content elements. In this way, we were able to map - into DOBM format - any content descriptive rules, to reference the external binary data file, and to use the Internet browsers as the basic presentation tools in spite of all the problems of the time, especially in handling images and various character sets.

It is evident that the apparition of XML and its acceptance by Internet browsers was the desirable solution for us later, but in spite of this our SGML-based approach had given us the necessary flexibility and it also made it easier to do the complete migration of entire compound documents onto a new XML platform in 2002.

## 2.2 Metadata

The solution for the Manuscriptorium schema was found in combination of our good practice - achieved in work with compound SGML documents - with newly emerging description standards for electronic records of manuscripts and still digital images. Thus the main three component parts of the DTD were bibliographic description of manuscripts based on TEI and known later as a MASTER (Cover, R., 2001) format, technical description of still digital images based on the future NISO standard Z39.87, and the page description based on our experience with various problems of foliation and pagination of manuscripts and other rare historical documents.

As we had to incorporate the technical elements also in the MASTER part of the future schema, we started to call the modified MASTER format as *masterx.dtd*. Later we had to introduce also some more granularity concerning old printed books that were not originally the target of the MASTER development efforts. Nevertheless, the *masterx.dtd* remained highly compatible with the original *master.dtd* in the main descriptive segment.

The resulted *msnkaip.xsd* continued to build a standard Czech way for encoding of manuscripts and it became the required format in the national grant digitization programme opened by the Ministry of Culture in the year 2000 for all institutions registered as public libraries. Thanks to this, almost 40 Czech institutions have contributed with their content to the future Manuscriptorium Digital Library. These are not only research libraries, but also libraries from museums, archives, universities, monasteries, or castles. In this way, the foundation for virtual building of a large manuscript digital library was laid on a very solid basement.

Later, several foreign institutions showed their interest to contribute with data to Manuscriptorium. These were, for example, University Library in Bratislava (Slovakia), University Library in Wroclaw (Poland), National Library of Turkey, and others. This fact as well as cooperation with many others pointed to the problem that Manuscriptorium should be able to deal both with MARC records and TEI-based records, both groups showing a lot of variety of individual approaches. Furthermore, a new TEI platform P5 arose and some institutions started to use it instead of the original MASTER TEI P4 version.

This was the situation before the ENRICH project was written. The positive fact was that our document formats (be they SGML or XML-based) always insisted very much on good expression (mark-up) of the (bibliographic) description of the document as such and also on the description of its structure or its structural map. The later analysis showed, however, that in both cases the behaviour of various content owners was different and that we had to adopt a lot of flexibility in order to be able to handle their documents or even to talk to them. Both the description and the structural map are crucial for content aggregation on-line.

## 2.3 Data

It is interesting to observe our thinking as to stability for digital documents over time. When starting, we were rather concerned about the stability of electronic information, and it seems that this concern was stronger in case of digital image formats than in case of metadata where we felt relatively safe thanks to adoption of the SGML platform.

Our approach developed from simple bitmaps to the usage of JPEG and it remained so until today. The Manuscriptorium applicable formats are those recommended for the web, i.e. JPEG, GIF, and PNG. At a time we considered also the acceptance of JPEG2000 for high-quality colour images, but after some testing and due to its low penetration in market we declined this solution.

We have enough experience with DjVu in another national digitization programme (newspapers and other modern documents published after 1800), where it is the main presentation format, and also with MrSID that is the only wavelet format used marginally in Manuscriptorium for digitized historical maps.

The classical JPEG proved to be very reliable and flexible; for presentation purposes, the only changes may be reconsideration of the lossy compression ratios or resolution at certain times and a new production of better JPEG presentation images from the archival image files.

In the beginning, the best Manuscriptorium images from our production were watermarked in a slightly visible manner to avoid their misuse. Neither the best quality images available were shared on the net.

Each page of a manuscript is usually represented by a set of images of different quality levels as to resolution, compression, and image depth. The full Manuscriptorium document has at maximum the following set of images for each page: a thumbnail image (called usually gallery image) in GIF or PNG, a bit larger preview image in PNG or JPEG, a black-and-white large image in GIF or PNG, a low quality image (already very

good for research and study) and a normal quality image (best representation for presentation purposes), both in JPEG. Recently we have started to consider also provision of high-quality images.

## 2.4 Storage and accessibility

The digital documents produced in the Czech national digitization programme are archived still on compact discs in more copies. The CDs have archival quality that has been achieved through cooperation with a Czech CD producer. They are stored separately in good conditions and regularly measured as to their physical and digital properties. The archival quality is going to be stored also in the national digital repository that is tending to become a trusted one in the near future. The Manuscriptorium Digital Library is working with a separate set of data that have been generated from the archival ones for presentation purposes.

The Manuscriptorium Digital Library is freely searchable up to the level of preview images, while the full access is licensed. The license can be bought (150 EUR for institutions and 75 EUR for individuals) or obtained through cooperation, because any contributing institution gets free access to all content for all its workstations.

Furthermore, Manuscriptorium communicates with and it is basically searchable through TEL, The European Library, via the OAI protocol – a DC record is offered for harvest.

## 3. COOPERATION AND AGGREGATION OF DATA

The above discussed features are now confronted with various different approaches of new content partners, be they direct ENRICH partners or the new associated ones. This fact leads to redefinitions of several aspects of the above approaches especially with the aim to achieve the maximum digital library flexibility in data aggregation.

The major principle in the data aggregation area is based on the concept of the compound document, i.e. on the possibility to fill in the structural map of the digital document with any binary data (mostly images) that are available on Internet.

In this way, we should be sure that the placement of digital images on partner servers is stable and the images are available anytime they are called by the digital library application. This has also impact on the administration of Manuscriptorium that started with its own image databank, while from nowadays onwards it will be also coping with existence of and cooperation with an increasing number of remote databanks.

Basically, such work foresees existence of contractual agreements through which Manuscriptorium gets the right to handle the images for presentation purposes, while their ownership continues to be held by the partner institutions that also get – via a Sub-License Agreement – the full access to the entire Manuscriptorium content.

A normal quality image is thus referenced in the following way as it is the case of the National Library of Romania:

```
<pgImage id="ID0003"
href="http://virtual.bibnat.ro/manuscriptorium/CR_XVI_II_4/n
ormal/CR_XVI.II4- Molitvenic Targoviste 1545 -
00000005.jpg" quality="normal"/>
```

It is also important to indicate the quality, because the Manuscriptorium viewer enables the selection of the quality provided that more images of various quality levels are available for a single page as it is in most cases.

Given this principle, the question to solve is:

- how to get the bibliographic descriptions of the documents to be presented;
- how to collect the document structures with links to existing images provided the partner digital library is built on similar principles and the presentation images are in JPEG, PNG, or GIF.

To set up the necessary strategies, an analysis of partner approaches has been made.

### 3.1 State-of-the-Art of Partners Data

**3.1.1 Bibliographic descriptions:** There are two big communities as to (bibliographic) description of manuscripts:

1. the classical library approach using - in most cases - a MARC record
2. a specialized approach using an extended mark-up based on TEI P4 or P5

To this, it is necessary to add the existence of various ad-hoc formats or even non-existence of electronic descriptions.

As to quantity and prevailing solutions, a usual approach is mostly a MARC record. This demonstrates the fact that the electronic description of manuscripts is in most cases an add-on to routine library work and when the manuscripts are digitized, the existing library systems are used for their presentations as far as it is possible or there are no presentations at all. Usually, such an approach does not lead to more sophisticated digital libraries of manuscripts, while the cooperation with them may be problematic, as it affects often also the structural maps of the documents and even the applied image formats in favour of JPEG2000, driven by some digital library applications and/or fashion.

On the other hand, such applications should be able to offer metadata for harvest easier as this should be a built-in feature of commercial integrated library systems.

The TEI communities are in development from TEI P4 to TEI P5 and in case they work also with digital library applications, their approaches are more open and well suitable to data integration into Manuscriptorium. They may use the MASTER format and the images are usually referenced or in TEI itself or via another structural map. Very often, such digital library applications are OAI harvestable.

The main question that arises from here is whether we should establish a common internal format for Manuscriptorium (now it is MASTER) and whether this should be TEI P4 or already P5. After many considerations, it has been concluded that due to variety of incoming formats, Manuscriptorium should be able to preserve them and handle them or most of them as such, i.e. to index them and make necessary transformations for display. In other words, there will not be any main or common format, but a container for recommended descriptions.

To be able to deal with that question properly, an analysis will be done to compare the TEI solutions with MARC approaches in order to establish the necessary granularity that would enable the output of both TEI and MARC records from Manuscriptorium authoring tools that are being prepared to support creation of input for Manuscriptorium.

Such tools could thus equally work for Manuscriptorium as well as for existing electronic catalogues in cooperating libraries. In this way, especially those who start with electronic descriptions of manuscripts would not feel Manuscriptorium to be a foreign element.

In most cases, libraries have already some electronic descriptions of manuscripts in their systems, but even in case they have also digital images, in many cases they have no structural maps able to be harvested or input after necessary transformations.

From the point of view of data aggregation, the two situations impose fewer problems:

1. The partner digital library of manuscripts is based on TEI or on a XML schema, the images are duly linked from within the TEI/XML structure, and the library is OAI harvestable (this is, for example, the case of digital libraries administered by the Cologne University Computer Science in Humanities Department or the Heidelberg University Library); in this case the OAI profile is to be agreed and the compatibility of used schemas checked;
2. The partner has no digital library and agrees with preparation of data for Manuscriptorium; with this, it starts to build its own digital library; for this a repository for images is needed and staff able to use the Manuscriptorium authoring tools (the good example is the National Library of Romania as our associated partner).

Unfortunately, there are a number of mixed solutions based mostly on existence of electronic records that should be converted to save time or non-existence of OAI communication. Anyway, transformation routines have to be created in such cases to support on-line or off-line connection of their digital libraries or mere image banks. For the purpose of our work, such solutions are named connectors.

**3.1.2 Structural maps and images:** In many cases, there are no metadata about the structure of the document, while in some cases, only the sequence of images is known. However, the maximal requirement for structuring manuscripts is to mark up their existing foliation or pagination, because as such the folios are usually cited. In many cases, this will not be possible, and we will have to be satisfied only with a sequence of existing pages/folios. In many cases, the structure will have to be created via our authoring tools. Even if it is not a generally applicable rule, in this area, the usage of TEI/XML for description of manuscripts mostly indicates that there is also a structural map or a good understanding of what this should be.

Independently of concrete variations in this area, for the internal management of information in Manuscriptorium, this means that we should be able to deal both with the bibliographic records and the structures rather independently. This is basically guaranteed by the internal containerization of the

schema elements in the so-called Complex Digital Document in which we mapped our schema into METS.

The METS approach was chosen, as it offered a framework to what we always wished to do, i.e. especially to administer more descriptions in parallel. In other parts of the document schema, there was no stress for new solutions, as the applied schema already contained all the necessary elements needed for our work.

Another problem consists in a variety of image formats used for the representation of the original. Even if the main format is mostly JPEG, there are also other approaches implemented most probably from various reasons. The first reason seems to be usage of more general tools for creation of digital libraries that are coming with certain recommendations. A usual fashion recommendation is application of JPEG2000 that may create a problem.

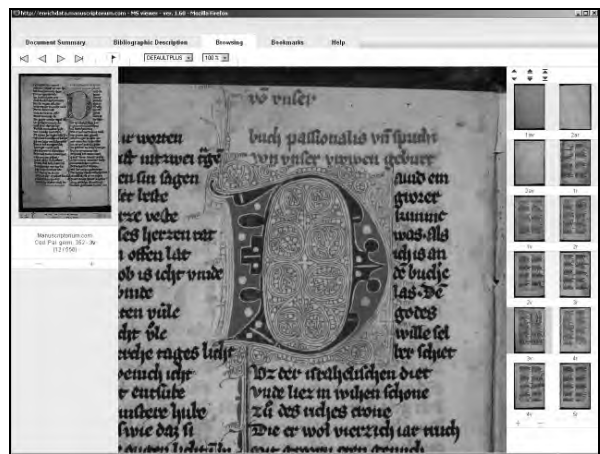


Figure 1: A manuscript from the Heidelberg University Library

### 3.2 Further Steps of Manuscriptorium Development

We have not accepted this format for Manuscriptorium, because it depends on tools produced mostly by a single company (LuraTech) and it is not recommended for the web, i.e. there is no native (built-in) JPEG2000 handling in Internet browsers; furthermore, one of the biggest segments of the digital imaging – massive usage of digital cameras by citizens – is almost exclusively based on the classical JPEG. At interesting compression ratios, the wavelet artefacts are disturbing the perception of digitized manuscripts in true colours more than a texture-like square JPEG artefacts, while a lighter wavelet compression outputs the files whose volume presents no considerable advantage over the performance of the JPEG DCT performance.

A problem how to structure the document may be on the basis of the application of PDF and/or DjVu-bundled files for presentation of entire documents, because the multi-page files contain the given sequence of pages. In spite of the fact that in general these are not happy solutions – even if in some cases they may be user friendly or practical – we will have to extract and convert the images into JPEG – or PNG/GIF in case of the black-and-white images.

For the moment being, we are not planning any dynamic image extraction and conversion routines with automated

Manuscriptorium-compatible structural mapping. We think that ad-hoc conversion or routines will be prepared to enable preparation of compatible imaging solutions by contributors.

There are two interdependent areas in which Manuscriptorium will be enhanced:

- content
- tools for adding and developing content

The crucial indicator for the success of the project is the number of new partners coming with content. ENRICH must have good dissemination activities and good examples to follow. The tools will facilitate the efforts of new contributors and attract new users of the shared digital library.

#### 4. ENRICH ADDED-VALUE

From the point of view of Manuscriptorium, there are two big groups of users: researchers (or users as such) and contributors. For both groups a lot of things will be done in order to create more comfort for their work.

##### 4.1 Personalization for Researchers/Users

The Manuscriptorium content is very heterogeneous even today from the point of view of provenance of digitized originals and the languages and characters in which they were written: for example, there not only the so-called Western manuscripts in various languages, but also documents written in Cyrillic (Old Slavonic and Romanian), Greek, Arabic (here also Persian and Ottoman manuscripts), Hebrew, or various Indian languages. Recently tests have started with Korean documents, using Korean and Chinese characters. To this it is necessary to add also various cataloguing/description languages; even now there are for example records using the less-known languages, as Czech, Slovak, Lithuanian, Romanian, or Turkish.

Also typologically there is an interesting variety of forms or/and content: manuscripts, rare old printed books, or historical maps; or from another side: manuscripts containing music, those created in the same scriptoria, etc. This fact shows that it will be wise to organize the Manuscriptorium content in certain collections that could make user orientation easier, as it is not always easy to find everything relevant due to various quality levels of descriptions made by different contributors. For example, we have been already asked several times about availability of Persian manuscripts. We know that even nowadays they are presented by at least three Manuscriptorium contributors, but it is very difficult to show them quickly together.

Furthermore, each document in Manuscriptorium usually consists of hundreds or thousands of analytical objects, mostly pages. We wish to give the users the opportunity to use the objects independently of their relationship to concrete originals and to create from them new virtual documents that could be successfully used for example for teaching purposes, being assigned to concrete individual virtual user libraries.

To this, we would like to add a possibility of automated translation between several languages and possibly to introduce some historical ontologies even if here we are unsure about how far this kind of tools will be efficient in a so complex and

complicated environment in which modern languages occur together with their old stages of development.



Figure 2: Music manuscript of the 18<sup>th</sup> century by the Czech composer František Xaver Richter from the Library of the Lithuanian Academy of Sciences in Vilnius

##### 4.2 Personalization for Contributors

There are basically two groups of contributors: those who work for their own digital libraries and have them and those who have digitized relevant content without being able to present it now on the web. Of course, there are many cases in between these two groups. Whilst the first group should be ideally OAI-harvestable and after application of necessary transformation routines their content added, the second group should be supported to create Manuscriptorium-compatible documents, i.e. the XML files in conformance with our schema. From the groups in transition between these two, a support to create structural maps with references to images placed on chosen servers is felt to be desirable.

Today, the contributors, who need to do some authoring work on their XML files, can use the freely downloadable M-TOOL software that supports basic description of the document, automated numbering of pages or folios, and binding of the structure with remote images.

The first problem encountered in the available M-TOOL version has been the handling of various character sets on various Windows platforms. However, The ENRICH analysis has shown also additional requirements that could be placed under a common denominator called enhanced flexibility. This flexibility will have to address main cataloguing or description requirements in interested institutions and a possibility to create incomplete or partial structural maps for the cases when only several pages are digitized as samples for the whole manuscript.



Figure 3: From a book of watercolour drawings of the 18<sup>th</sup> century shared by the Italian National Library in Florence

The needed flexibility together with solution of the problem of various character sets will be solved in the new on-line version of the M-TOOL to appear in autumn 2008. The main condition for its preparation is the planned analysis of different and common points of TEI and MARC description approaches, as the new tool should feed both the Manuscriptorium and local MARC-based OPACs. It is evident that the output transformation will vary from institution to institution on the basis of concrete MARC application and interpretation for manuscripts and/or historical documents.



Figure 4: From a plan of the port in Saint Feliu de Guixols shared by the National Library of Spain in Madrid

Even now the XML-authoring contributors are given access to the on-line Manuscriptorium for Candidates application where they can test the results of their work in an environment similar to Manuscriptorium. When they are satisfied, they can change the status of their documents and offer them for review. The assigned reviewer can return the document for further improvement or recommend it for upload. A special Manuscriptorium clone for ENRICH has been built up to provide final opportunity for interested parties to check the completeness and the quality of the documents proposed for Manuscriptorium.

## 5. CONCLUSIONS

The ENRICH project marks an important period in the development of the Manuscriptorium Digital Library. This library was fully functional before the project and it should be here also when it is completed. A great challenge is its sustainability. For the time being, it is supported by the Czech Ministry of Culture and the National Library of the Czech Republic, while its existence would never be possible without creative interest of AiP Beroun Ltd.

ENRICH is bringing new contributors with new content; it is also stimulating many other institutions in Europe and even out of Europe to join us. The dispersed collections are merged again at least virtually, researchers do not need to travel and can concentrate on their work, institutions with digitized content that has not yet been presented on-line get new opportunities and can tune and localize their own virtual clones of the main Manuscriptorium.

Manuscriptorium is enhancing access to manuscripts and other rare documents, it brings them into new contexts, it shows that it is worth to build specific virtual environments along with general portals and access points, because they can integrate information more in detail and in depth, while providing services oriented to selected users, in this case researchers.

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# **CH Digital Representations**



## STANDARDS, METADATA, ONTOLOGIES: CULTURAITALIA TOWARDS THE SEMANTIC WEB

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**KEY WORDS:** Application Profile, Cultural Heritage Domain, Encoding Schemes, Metadata Crosswalks, Metadata standards, SKOS, Thesauri, Web Portals

### ABSTRACT:

The Portal of Italian Culture, named *CulturaItalia* describes digital resources and physical resources pertaining to the whole cultural heritage domain using a specifically conceived Application Profile based on Dublin Core (PICO AP). Metadata are used to describe cultural resources both at item and at collection level. The DC PICO AP allows the integration and interoperability of data on different sectors of cultural heritage, with the overall objective to merge all these contributions into Europeana.

The PICO AP supports some encoding schemes, such as international standard and thesauri or ontologies. Moreover, a specific Thesaurus has been defined in order to describe the Italian cultural domain and to give a hierarchical order to the resources available into Index of *CulturaItalia*. The new updated version of the PICO Thesaurus has been expressed in SKOS to promote the context of Semantic Web Deployment in the different national Informative Systems and to share it in international projects.

The paper introduces *CulturaItalia* and the special Application Profile, defines and comments the new terms introduced in the AP, together with some examples of how original structured source information has been mapped into the AP, adopting DCSV syntax and creating further encoding schemes.

### 1. INTRODUCTION - THE PROJECT FOR ITALIAN CULTURE PORTAL

The Italian Ministry for Cultural Heritage and Activities (MiBAC) committed to Scuola Normale Superiore di Pisa (SNS)\* the scientific and technical project for *CulturaItalia* (SNS – Scuola Normale Superiore di Pisa, 2005). The portal [www.culturaitalia.it](http://www.culturaitalia.it) is on-line since April 2008. *CulturaItalia* aims at providing the user with one access to various and distributed data sources. The policy adopted by MiBAC is to avoid data duplication and to harvest metadata through OAI-PMH.

The Portal is targeted to general users, by offering them a service for retrieving resources on Italian culture from one point of access, and to more expert users, such as the operators in the field, who can take advantage of a high-quality showcase to promote their own cultural digital resources.

After retrieving the resource of interest in *CulturaItalia*, the user can directly access to the data source, by heading to the provider's website or by contacting it via other channels, in order to find out more information about the resource.

The Portal gives access to a database of “metadata” which gathers and organises the information arriving from the various providers participating in *CulturaItalia*. Users can discover different kinds of digital resources which make up the country's extensive cultural heritage (museums, photographs, libraries, archives, galleries, exhibits, monuments, videos, discs, etc.).

*CulturaItalia* is an “open” system: it grows up and develops together with the continuous enrichment of its metadata repository.

The Portal repository is constantly provided of updated contents through the metadata harvesting according to OAI-PMH, a protocol which allows the harvesting of metadata from content providers to one or more harvesters, adding services as indexing system or automatic classification. The Portal harvests metadata from different repositories and exports metadata to other national and international Portals and repositories.

A specific Dublin Core Application Profile has been designed in order to cover the complex domain of the “Italian Culture” and to guarantee the interoperability of various kinds of cultural resources, allowing the retrieval and indexing of digital cultural contents available through databases, websites, etc. This application profile is called PICO AP (SNS – Scuola Normale Superiore di Pisa, 2007) from the name of the Project in whose context the *CulturaItalia* portal was developed (PICO is the acronym for “Portale della Cultura Italiana On-line”).

Following DCMI recommendations, SNS defined an application profile which joins DC Element set, Qualified Dc terms and some further refinements and encoding schemes conceived for the application of *CulturaItalia*.

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The screenshot shows the Culturaitalia website interface. At the top left, the logo 'cultura italia' is displayed with the tagline 'UN PATRIMONIO DA ESPLORE'. Below it is an 'Indice' section with a 'Consulta l'indice' link. A 'Temi' sidebar lists various categories like Archeologia, Architettura, and Letteratura. The main content area displays a record for 'Villa Doria: palazzo' with the following metadata:

- Tipo:** Immagine fissa - Immagine - Oggetto fisico - Forma specifica dell'oggetto: negativo
- Categoria:** Fotografie
- Descrizione:** Inquadratura: campo lungo
- Soggetto:** Architettura
- Materia e Tecnica:** gelatina bromurò d'argento/vetro b/n
- Misure:** numero di foto: 1
- Data:** 1928
- Ambito geografico:** Pegli villa Doria a Pegli
- Provenienza:** Istituto Luce
- Data di creazione:** periodo fascista [1919 - 1943]

Additional sections include 'Riferimenti' (E' incluso da: titolo del servizio fotografico di appartenenza: Pegli), 'Fonte Dati' (Istituto Luce - LuceSerie L, Identificatore: IL0000029604), and 'Diritti' (Detentore dei diritti: Istituto Luce). The footer contains the date 'Ultimo aggiornamento 21 febbraio 2008' and copyright information for the 2006-2008 Ministero per i Beni e le Attività Culturali - Culturaitalia Versione 1.3.

Figure 1 – A screenshot of Culturaitalia displaying metadata pertaining to a record harvested from the provider Istituto Luce

## 2. CULTURAITALIA DOMAIN: THE CHOICE OF DUBLIN CORE

The project moved from the analysis and definition of the domain. "Italian culture" is a wide concept, perceived in different ways according to users' education and interests and changing over time.

MiBAC is responsible for preservation, management, research and promotion of the Italian cultural heritage, both tangible and intangible. Tangible heritage includes: architecture and landscape; artworks and art collections, from painting to applied and decorative arts; archival records; manuscripts, printed books, as well as contemporary literature; archaeological and ethno-anthropological objects; contemporary art and architecture. Intangible heritage includes music, cinema, any kind of performing art, such as dance, theatre or circuses, folk feasts and traditions.

Within such a wide domain, contents are extremely varied. In addition, Culturaitalia gives access to digital cultural resources

belonging to other main cultural institutions at Regional and local level, to outstanding private organisations and also to the main expressions of humanities and scientific culture (people, cultural events, institutes as well as projects).

New content providers will be constantly contacted for joining the project, thus it is not predictable which kinds of contents will be represented into the Portal and in which formats. Therefore a data model with predefined entity types seemed unsuitable: designing one metadata schema has been preferred as a more flexible solution, able to assure the scalability of the whole system.

The first phase of the project produced an analysis of the state of the art. The most used models for data description were taken into consideration and examined in depth. Amongst them must be mentioned: *VRA Core 4.0* (VRA – Visual Resources Association, 2007); *CDWA* (Getty J. P. Trust, College Art Association, Baca M. - Harpring P., 2006); *CIMI Profile 1.0* (Consortium for the Computer Interchange of Museum Information (CIM) CIMI Z39.50 Working Group, November 1998); *CIDOC object-oriented Conceptual Reference Model (CRM)* (CIDOC-CRM – ICOM / CIDOC

Documentation Standard Working Group, 2000), focussing mainly on art objects; *EAD 2002 Schema*, (EAD 2002 – Library of Congress,

2002); *MARC Standards* (MARC 2007 - Library of Congress, 2007),

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- <OAI-PMH xsi:schemaLocation="http://www.openarchives.org/OAI/2.0/ http://www.openarchives.org/OAI/2.0/OAI-PMH.xsd">
  <responseDate>2008-06-24T10:30:38Z</responseDate>
  <request identifier="IL0000029604" metadataPrefix="pico" verb="GetRecord">http://www.regesta.com/oaiat/OAIHandler</request>
- <GetRecord>
  - <record>
    - <header>
      <identifier>IL0000029604</identifier>
      <datestamp>2007-12-14</datestamp>
      <setSpec>LucaSerieL</setSpec>
    </header>
    - <metadata>
      - <pico:record>
        <dc:type xsi:type="dcterms:DCMIType">StillImage</dc:type>
        <dc:type xsi:type="dcterms:DCMIType">Image</dc:type>
        <dc:type xsi:type="dcterms:DCMIType">Physical Object</dc:type>
        <dcterms:rightsHolder>Istituto Luca</dcterms:rightsHolder>
        <dcterms:provenance>Istituto Luca</dcterms:provenance>
        <dc:identifier>IL0000029604</dc:identifier>
        <dc:title xml:lang="it">Villa Doria: palazzo</dc:title>
        <dc:description>Name=inquadratura; Value=campo lungo</dc:description>
        <dcterms:created xsi:type="dcterms:W3CDTF">1928</dcterms:created>
        <dcterms:extent>Name=numero di foto; Value=1</dcterms:extent>
        <dc:type>Name=forma specifica dell'oggetto; Value=negativo</dc:type>
      - <dcterms:tableOfContents xml:lang="it">
        Il prospetto rinascimentale della villa, con ali laterali loggiate, affacciantesi su un ampio piazzale con viali e aiuole.
      </dcterms:tableOfContents>
      <dcterms:spatial>Pegli villa Doria a Pegli</dcterms:spatial>
      <dc:subject xsi:type="pico:Thesaurus">Name=Fotografie;ID=2000900000000000</dc:subject>
      <dcterms:temporal xsi:type="dcterms:Period">Name=periodo fascista; start=1919; end=1943</dcterms:temporal>
      <dc:subject>Architettura</dc:subject>
      - <pico:preview xsi:type="dcterms:URI">
        http://151.1.148.222/foto/thumb/LL048/L00002926.JPG
      </pico:preview>
      - <dcterms:isPartOf>
        Name=titolo del servizio fotografico di appartenenza; Value=Pegli
      </dcterms:isPartOf>
      <pico:materialAndTechnique>gelatina bromuro d'argento/vetro b/n</pico:materialAndTechnique>
    </pico:record>
  </record>

```

Figure 2 – The same record as figure 1, as it appears into the OAI repository of Istituto Luca

used in the Archives and Libraries domain.

The most relevant thesauri concerning cultural domain have also been taken into consideration, from the cultural sections “Culture” of *UNESCO Thesaurus* (UNESCO, 1977) to *ULAN* (The Getty, 1994) and *AAT – Art and Architecture Thesaurus* (The Getty, 1990), issued by Getty Research Institutes.

All these models and thesauri are dedicated to specific domains, but they are not suitable for such a wide range of contents. For this reason, Dublin Core metadata standard (DCMES – DCMI, 2006) has been adopted, as a more general metadata model, able to assure interoperability between systems using very different data models, giving as well the opportunity to introduce specific refinements.

### 3. THE PICO APPLICATION PROFILE

Dublin Core allows to describe “anything that has identity”, distinguishing different kinds of resources by the element <dc:type>. However, it has been pointed out that DC Element Set may not be completely effective for the description of some kinds of cultural resources, as it groups into general elements

pieces of information that are commonly perceived as separated in the cultural domain, such as spatial and temporal coverage.

For this reason, Dublin Core Metadata Initiative itself developed the Qualified DC, introducing Element Refinements and Encoding Schemes (DCMI–Terms – DCMI, 2006) to assign to a given property a value selected from a controlled vocabulary, a thesaurus, or an ontology.

Thanks to dumbing down algorithms, which reduce Qualified DC values into Simple DC values, interoperability with other system adopting DC is assured, loss of information is reduced and retrieval is more effective (for the dumbing down, cfr. DCMI Abstract Model – Powell A., Nilsson M., Naeva A., Johnston P., 2005).

The project adopted the DCMI suggestion to develop DC Application Profiles for specific applications and domains, joining (all, or a selection of), DC Elements and Refinements, elements from one or more element sets and elements from locally defined sets.

The *PICO AP* combines in one metadata schema all DC Elements, all DC Element Refinements and Encoding Schemes from the Qualified DC and other refinements and encoding schemes specifically conceived to retrieve information pertaining to Italian culture.

The decision to avoid the introduction of new elements, adding solely new element refinements and encoding schemes, was due to the priority of assuring total interoperability with system based on DC. The following namespaces are included into the metadata schema: 'dc:', 'dcterms:', 'pico:'.

This Application Profile could be further expanded for harvesting possible unexpected contents in the future, by adding Refinements and Encoding Schemes that could be suitable for data retrieval.

The *PICO AP* (SNS – Scuola Normale Superiore di Pisa, 2007) has been recently improved on the basis of the first mappings performed on some data-models or metadata schemas related to contents to be harvested by CulturalItalia, specially adding encoding schemes to express uniformly relevant information, such as addresses.

An official publication of the *PICO AP* (SNS – Scuola Normale Superiore di Pisa, 2007) has been developed according to the DC Application Profile Guidelines (CWA 14855 – European Committee for Standardization, 2003), issued as the CEN Workshop Agreement CWA 14855, thus declaring definitions and constraints (Obligation, Condition, Datatype and Occurrence).

The *PICO AP* can be consulted at: <http://purl.org/pico/picoap1.0.xml>. Schemas used for the *PICO AP* are published on the following PURLs, under the domain PICO: <http://purl.org/pico/1.1/pico.xsd> and <http://purl.org/pico/1.1/picotype.xsd>.

#### 4. USE OF DCSV SYNTAX

The mappings already performed on different databases for generating *PICO AP* metadata sometimes have brought into light the problem of representing hierarchically structured information, which is a case study that often occurs in the cataloguing charts pertaining to Italian heritage.

The idea was to maintain DC and PICO terms and to introduce into the metadata strings significant labels for representing the hierarchies conceived in the original data models, specially for repeatable properties, which could lose their meaning if reduced to a plain Dublin Core value.

Therefore, a solution has been identified in the use of the Dublin Core Structured Value syntax (DCMI–DCSV – Cox S., Iannella R., 2006).

An example can be derived from the activity of generating metadata from the database of Italian Institute of Catalogue and Documentation (ICCD – Istituto Centrale per il Catalogo e la Documentazione), the national institute for the cataloguing of Italian tangible heritage.

The property “Previous Location” of a movable art object – which can be repeated when the artwork has moved in different collections or museums – is expressed in a hierarchical series of

properties, conceived as subfields of the field “Previous Location”: region, name of the collection, address, etc.

By mapping each value coming from those subfield in a single Dublin Core element (dc:provenance), information on the resource would be mixed into the element “provenance”, thus producing a huge loss of meaning.

DCSV syntax allows to express into the string of a single DC element, a significant label and its value, divided by a semicolon ( ; ) and to separate hierarchical properties with a dot ( . ), e.g.: name= labelname; value= valuestring.

This way, it has been possible to express values like: <dc:provenance>typeOfPreviousLocation=Place of provenance; PreviousLocation.State=Italy; PreviousLocation.Province=RM; PreviousLocation.Name=Borghese Collection</dc:provenance>.

#### 5. EXTENSION TO THE DCMI TYPE VOCABULARY

One of the most relevant extensions of *PICO AP* is the introduction of three more types. The DCMI Type Vocabulary (DCMI–Type – DCMI Usage Board, 2008), originally conceived for the description of digital resources, appeared not completely efficient for the large domain of CulturalItalia. Thus, the *PICO AP* extended the DCMI Type Vocabulary by introducing the PICO Type Vocabulary (SNS – Scuola Normale Superiore di Pisa, 2007), a controlled vocabulary which adds the types ‘Corporate Body’, ‘Physical Person’ and ‘Project’.

These three new types have been suggested also by the need to map into the *PICO AP* the five entities of the data model produced by the European Project MICHAEL – Multilingual Inventory of Cultural Heritage in Europe, [www.michael-culture.org/it/](http://www.michael-culture.org/it/), designed for the description of digital cultural collections, which will be a content provider for CulturalItalia.

The PICO Type vocabulary defines the three new types as follows:

- **Corporate Body:** any public and private, Italian and foreign organisations in charge of preservation, management, research, promotion of cultural heritage and activities. Corporate Bodies can be mutually related; a Corporate Body can be responsible and/or owner of physical objects, events, collections, products and services.
- **Physical Person:** any physical person, dead or alive, related anyhow to other resources (artists, novelists, scholars, performers, publishers, etc.). Physical Persons can be in various ways responsible for the creation, publishing, management of a resource, a project, an event, etc.
- **Project:** Italian and international initiatives in the field of research, preservation, management, access, promotion of cultural heritage and activities, in which Corporate Bodies and Physical person can be involved in different ways. Projects may digitize resources, create services or events, include or be related to other projects, etc.

## 6. PICO AP ENCODING SCHEMES

Encoding schemes are very useful for expressing values in only one way, providing un-ambiguous identifiers taken from thesauri, ontologies or taxonomies. Taking into consideration the domain of CulturalItalia, the PICO AP added encoding schemes for the description of:

- texts: pico:ISBN and pico:ISSN adopt, respectively, International Standard Book Number and International Standard Serial Number, as uniform and persistent identifiers for a given title or for the edition of a title pertaining to a given publisher.
- people names: pico:ULAN adopts the Union List of Artists Names, a controlled vocabulary by the Getty Research Institute (Getty Union List of Artist Names Online). In order to express such encoding scheme, it is recommended to use DCSV syntax, providing ULAN “Preferred name” as NAME and the “ID code” assigned by ULAN as VALUE (e.g. name=Cerquozzi, Michelangelo; value=500007713).

- place names: pico:ISTAT. ISTAT code is a number assigned by Istituto nazionale di statistica italiano (Italian National Institute for Statistics), which identifies inhabited places in the Italian territory (ISTAT – Istituto Nazionale di Statistica). The encoding scheme ISTAT uses DCSV syntax with the following component labels: NAME (optional); YEAR (year of formal issuance of the code. Optional: “1991”, “2001”. Default: “1991”); CODE - ISTAT code composed by 12 numbers (when YEAR = “1991”) or by 13 numbers (when YEAR = “2001”) obtained joining the codes of Region (2 numbers), Province (3 numbers), Municipality (3 numbers) and Locality (4 numbers if YEAR = “1991” and 5 number if YEAR = “2001”).
- subjects: pico:UNESCO adopts the UNESCO Thesaurus (UNESCO Thesaurus) for indicating the topic of resources on education, culture, natural, human and social sciences, communication and information. Multilingual: English, French, Spanish.

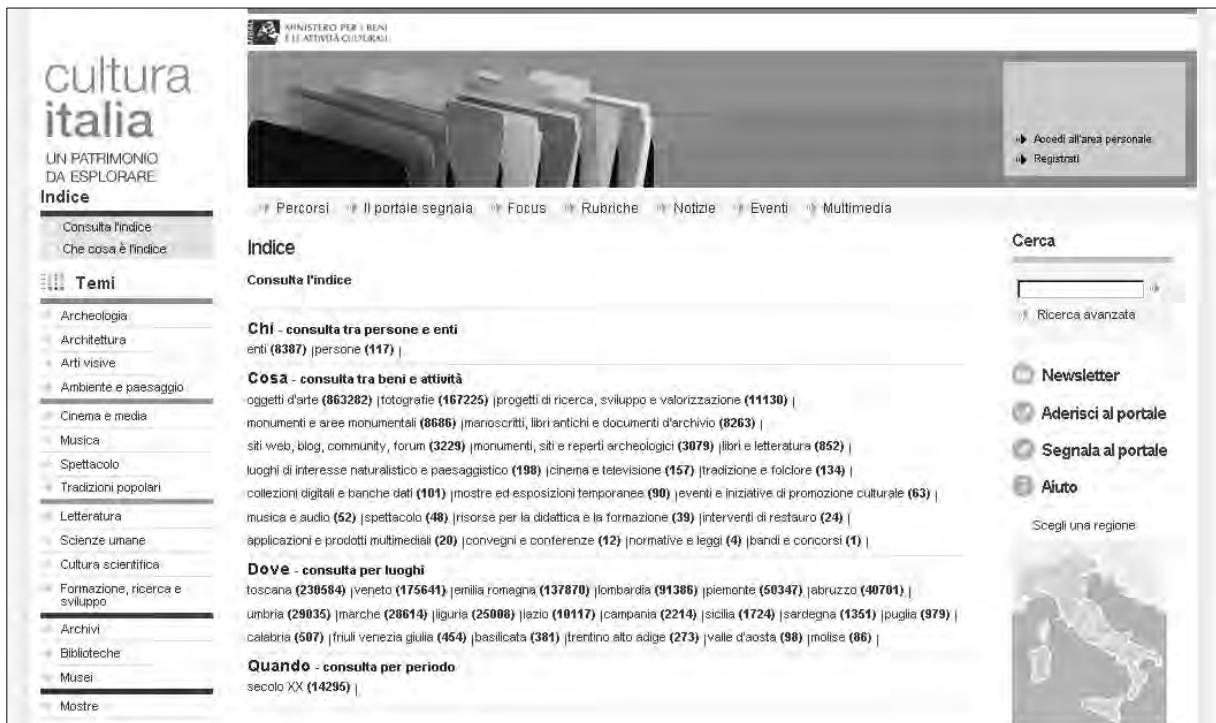


Figure 3 – The browsing into the Index of metadata in CulturalItalia is hierarchically organised on the basis of the PICO Thesaurus

- artworks subjects: pico:AAT and pico:ICONCLASS. pico:AAT adopts Art and Architecture Thesaurus defined by Getty Research Institute (The Getty, 1990) for indicating the topic of resources pertaining to art and architecture objects. It is recommended to use DCSV syntax for expressing AAT values, indicating as NAME, the ‘Preferred Name’ and, as VALUE, the ID code assigned by AAT (e.g. name=doric; value=300020111). pico:ICONCLASS adopts the ICONCLASS Taxonomy for iconographic subjects for the Western Art, from Medieval

to the Contemporary Art, available in English, German, Italian, French, Finnish (RKD - Rijksbureau voor Kunsthistorische Documentatie, 2006). It is recommended to use DCSV syntax for expressing ICONCLASS values. For the NAME, indicate the subject name, for the VALUE, use the related code. (e.g. name=angels fighting against other evil powers; value=11G34).

## 7. PICO THESAURUS

One of the most relevant encoding schemes introduced in the PICO AP is a Thesaurus specially conceived for the project itself, which comprehends hierarchically structured keywords indicating the topic of all the resources included into CulturalItalia (SNS – Scuola Normale Superiore di Pisa, 2007).

This ontology is also used to support the browsing into the Index of resources of CulturalItalia, therefore the assignment of a value taken from the Pico Thesaurus is mandatory for each metadata record.

During the metadata generation, this assignment can be created for a whole repository or for a whole set, while in some other cases it has been necessary to interpret a given value of the original database in order to create a mapping into the Thesaurus.

The PICO Thesaurus is organized in four main categories, derived from the four "High level elements of DC Culture, defined by the Aquarel project and approved by the MINERVA project (MINERVA Handbook – MINERVA Project, November 2003): Who, What, Where, When.

"Who" includes both people and corporate bodies; "What" comprehends tangible and intangible heritage, and all digital objects; "Where" covers Italian places (from regions to towns and villages) and "When" includes a list of chronological keywords associated to a sharp range of years.

Although this Thesaurus is presently used to associate each metadata record to the index of CulturalItalia, the development of the project and the first mapping experiences brought to define a new version of the Thesaurus (Trigari M., 2008) to avoid inconsistencies, to better cover the domain of Italian culture, to remove terminological ambiguities and up to date keywords, also taking into account a bilingual version in Italian and English and the possibility of future translations in other languages.

In order to be more compliant with international best practices, it seemed useful to adopt a SKOS format for the PICO Thesaurus 4.0.

SKOS (Simple Knowledge Organisation System), is a recommendation of W3C for the expressing systems for the organization of knowledge in the world of semantic web (W3C Semantic Web Deployment Working Group SWDWG, 2006). As an open source project, SKOS originated in 2003 from the SWAD-E (Semantic Web Advanced Development for Europe) project, with the aim of defining a thesaurus model compliant with the most important standard ISO (ISO 2788, ISO 5964).

W3C has been in charge of developing SKOS since 2004. In May 2005 the first draft has been published. This system is based on a Core Vocabulary conceived for easy further extensions; its main aim is to act as a connector amongst the most used KOS as libraries, museums and archives thesauri and new KOS born in relation with the Web, as open-directories or blog topic exchange.

SKOS Core Vocabulary consists in a series of RDF classes and properties to be used to represent the content and the structure of concept schemes as thesauri, controlled vocabularies, lists, taxonomies, glossaries and, in general, each kind of classification system.

Being in RDF format, such concept schemes can be modified, stored and can allow queries using RDF tools. Therefore SKOS can be used as an inter-exchange format between different digital libraries and is the most suitable tool to assure semantic interoperability amongst different KOS.

Version 4.0 of PICO Thesaurus is, in the end, conceived also to be extended and/or integrated by adding more specific thesauri, defined in more specific domains, where they have a standard role, or to support multilingualism by the comparison and mapping amongst different national KOS.

Such action will be one of the core objectives of the new EU project ATHENA, coordinated by Italian Ministry of Cultural Heritage and Activities and approved under the e-Content plus framework, aiming at providing the European Digital Library with item level contents in the Museum sector and to contribute in the development of best practices, standards and tools for the semantic interoperability in the European Digital Library itself.

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## MULTIFUNCTIONAL ENCODING SYSTEM FOR ASSESMENT OF MOVABLE CULTURAL HERITAGE

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**KEY WORDS:** Multiencode, Holographic techniques, cultural heritage, artworks, Impact Assessment Procedure.

### ABSTRACT:

This introductory paper of a recent EC project is dealing with research in cultural heritage and aiming to communicate new fields of application for optical metrology techniques. Nowadays safety, ethical, economical and security issues as well as the increase demand for loaning of art objects for exhibitions in transit, are forcing the Conservation Community to undertake strong initiatives and actions against various types of mistreatment, damage or fraud, during transportation of movable Cultural Heritage. Therefore the interest directs to the development of innovative methodologies and instrumentation to respond to critical aspects of increased importance in cultural heritage preservation, among which of prior consideration are: to secure proper treatment, assess probable damage, fight fraud actions in transportation.

### 1. INTRODUCTION

The MULTIENCODE aims to create a new standard way of monitoring the condition of artworks by using the latest holographic technology. It will produce innovative methods and tools which will allow conservators to assess the conservation state of an object and the need for any treatment; illustrate any new damage; monitor the impact of transport; and confirm a piece's originality. An object would undergo transient alterations to extract its distinct holographically encoded patterns before being digitally classified and archived. The coded data can then be easily retrieved to be compared with past and any future entries to assess changes to the object.

It is thus proposed in this project the development of a novel *Impact Assessment Procedure (IAP)* based on interference-signal direct encoding nature by exploiting and further providing to the conservation community the holographic technology advances and innovative tools for a highly secure encoding-decoding system of objects' features required in many critical aspects for sustainable preservation of movable artworks.

It may apply in many functional and strategic decision-makings in museums operation, from routine seasonal examination of conservation state, to periodic assessment of conservation treatments and materials compatibility, to deterioration control and definition of early-induced damage, to continuous monitoring of transportation impact, to direct confirmation of originality and control of maintenance for any art object in transit, etc.

The effective proposed method relies on the original coded extraction of distinct features from the artwork under conservation, transportation and loan that characterizes the state of conservation of the artwork and its originality. The coding

and decoding of such characteristic features can be performed holographically before and after have been optically and numerically transformed for digital archiving. The object features or the archived coded data forming the "signature" of the object can be recollected and compared through repeatable *IAP* at any later time to provide indication of induced alterations. The project advances the state of the art elaborating in synergy with existing methods and practices and concludes with specific novel instrumentation and standards for universal application and worldwide exploitation.

The proposed method advances the state of the art elaborating in synergy with existing methods and practices and concludes with specific novel instrumentation and standards for universal application and worldwide exploitation. It would enable us to make further progress on our previous research into the deterioration of objects through handling, transport and environmental conditions.

Europe's works of art, such as paintings and sculptures, are the lifeblood of Europe's cultural heritage. Museums put them on display and, increasingly, loan them out to other institutions. However, exhibiting art and moving it from place to place causes problems. Repeated handling, the need for conservation treatments and exposure to sudden environmental and climatic changes can all take their toll on old and delicate objects. Art in transit is also under threat from mishandling and fraud. Conservators need to monitor the condition of artwork in a way that responds to these issues. Structural and mechanical properties of artworks are an important factor of deterioration causing slow but steady disintegration of the artwork. The thermal and moisture related degradation processes, transportation and handling, various conservation and restoration actions, as well as the display and arrangement may systematically or rapidly influence the condition of the concerned artwork, monument or antique. A novel tool to help conservation researchers and practitioners to visualize the invisible defects, constant disintegration processes and

interventions has been introduced through the principles and targeted adaptation of holographic interferometry (Vest, 1979; Tornari, Zafropoulos, Bonarou, Vainos, Fotakis, 2000; Mieth, Osten, 2001; Tornari, Fantidou, Zafropoulos, Vainos, Fotakis, 1998).

The visualization of small or inborn discontinuities in the bulk and their consequences on the mechanical instability of the artwork construction can be optically and digitally obtained (Jones, 1989). The holographic technology is not based on light penetration but on reflection of diffused laser beams from the artwork surface. Holography and related techniques involved in structural diagnosis do not require any sample removal or surface preparation and are safe for use on varnishes and pigments. In this context, the techniques can be classified as non-destructive, non-contact and non-invasive.

The methodology to visualize the defects of interest is based on differential displacement provoked in time by two slightly different positions of the artwork reflecting surface of interest through relevant to material properties external excitation (Boone, Markov, 1995; Hinsch, 2000). The displacement results in a relative optical path change of the reflected beam significantly modulated by the excited bulk defects influencing the surface, which can be studied after have been optically or digitally converted to visible interference patterned signal. The procedure is repeatable and can be formulated to generate slight alteration at each record that would result in a thorough study of defect dynamics. Each patterning is an “encoded” response of the examined artwork and indicates its conservation state correlated with the known induced excitation and rest investigation parameters to a unique data termed *IAP* (*Impact Assessment Procedure*), as shown in Figure 1.

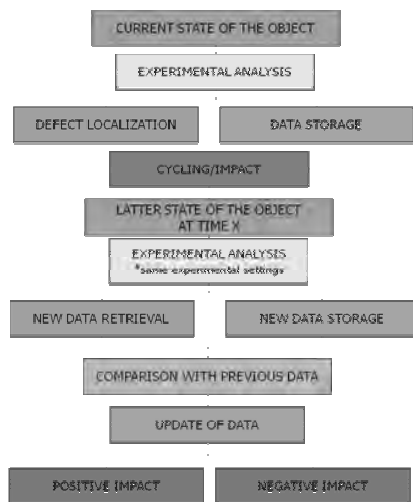


Figure 1: Impact Assessment Procedure

The holographic instrumentation allows investigation of a variety of recording media incorporating distinct properties as well as variety of optical combinations to repeatedly reveal the required data. Techniques based on reflected wavefield recording and specklefield imaging are explored through experimentation of artwork simulated samples and conservation protocols provided by conservators. At the time of writing encouraging results have been obtained by the application schemes and the overall research is still on progress.

In the following paragraphs are presented some preliminary results of each implemented technique in an effort to illustrate the concept of the project and the *IAP*.

## 2. EXPERIMENTAL

Holographic techniques are being under test for examination and classification of provided properties and advantages in regards to the aim of multi-task sensor and development of *IAP*. The starting stage of the project at the moment of writing does not allow any clear conclusion for the final decision which is expected at a later time according to the work plan. However the techniques under exploitation and indicative result are presented.

### 2.1 Digital Speckle Shearography

Shearography is a double exposure speckle interferometry which has sensitivity to the displacement gradient. The sensor optically differentiates light from the object in a shearing Michelson interferometer and does not require a separate reference. This is important because the interferometer is effectively common path and is therefore much more insensitive to environmental disturbances when compared with other full-field interferometric sensor types. Also the optical differentiation means the sensor is sensitive to displacement gradient, a parameter closely related to the strain field, rather than the displacement sensitivity of the other sensor types (Groves, Osten, 2006)

### 2.2 Digital Holography

The technique allows for the measurement of dynamic events with submicron accuracy and is therefore well suited for the investigation of surface deformations of thermally loaded art works (icons, canvas). Hundreds of holograms of the object that has been subjected to dynamic deformation are recorded. The acquisition speed and the time of exposure of the detector are adjustable to allow for surfaces deforming at different rates. The phase of the wave front is calculated from the recorded holograms by use of a two-dimensional digital Fourier-transform method. The deformation of the object is calculated from the phase. The software developed allows the visualisation of the deformation as a function of the time and for the detection of eventual defects (Tornari, Bonarou, Esposito, Osten, Kalms, Smyrnakis, Stasinopoulos, 2001).

### 2.3 Digital Speckle Holographic Interferometry

The technique allows the subtraction of the sequential alterations of a reflected by the artwork speckle field. An off-axis holographic interferometry arrangement is adjusted to capture via a cube beam splitter in front of the camera lens the interfering beams with angular separation of few degrees and moderated spatial frequencies resolvable by the CCD sensor characteristics. The technique permits extended field of view ( $\approx 30$  cm) of the object to be examined in real time and micrometric resolution of flaws be directly evaluated (Tornari, Zafropoulos, Bonarou, Vainos, Fotakis, 2000).

### 2.3 Photorefractive Holographic Interferometry

Photorefractive crystals of the BSO family ( $\text{Bi}_{12}\text{SiO}_{20}$ ) have been proved to be promising recording materials for holographic interferometry in the visible wavelength range (blue-green). In these crystals charge migration appears, under the photoconduction effect, between illuminated and dark zones



that result from the interference between two mutually coherent incident beams (an object and a reference). After charge trapping in crystal defects of the dark zones, a local space charge field is created and this modulates the refractive index, through the linear electro-optic effect, creating a phase hologram. This process is dynamic and reversible. The hologram is created within a certain time constant and then reaches a saturation level. The two important figures of merit to consider in applications are the diffraction efficiency and the recording energy density.

First, the diffraction efficiency is simply the ratio between the diffracted beam intensity and the readout beam entering the crystal. Photo-refractive crystals (PRCs) have relatively small efficiencies ( $10^{-3}$  to  $10^{-4}$ ) compared to other recording media. Nevertheless this is not a problem if one considers the special properties of the crystals such as the coupling effect or anisotropy of diffraction. Second, the energy density of recording is a constant of the material when several experimental parameters are fixed (e.g. wavelength, angle between beams, and value of external electric field). The energy density is the quantity of luminous energy by unit surface that is necessary to reach the saturation of holographic recording. For a BSO crystal with a  $50^\circ$  angle between recording beams and no electric field, its value is about  $10 \text{ mJ/cm}^2$ . This quantity is the product of the response time of the crystal and the total intensity of the recording beams. An important consequence is that the hologram can be recorded either with continuous or pulsed lasers. At the present state-of-the-art, one can say that PRCs have practically no limit in the response speed since they (at least in theory) respond at the nanosecond scale.

Besides this dynamic behaviour, PRCs present many interesting features. The first is that we can distinguish between two separate configurations, by the polarization state of the diffracted beam. These are anisotropy or isotropy of diffraction. In the function for a specific application we can choose the most suitable diffraction behaviour. Each one of these processes is controlled by a suitable choice of the direction of the grating wave vector with respect to the crystallographic axes, the polarization states of the recording beams and the direction of an external electric field. In the applications described here, no external electric field is applied. The reason is that, without an applied field, the diffraction is maximized at large angle between recording beams: This is more advantageous if one wants to use short focal lengths objectives in front of the crystal to observe large objects.

The typical methodology is to record a hologram within the crystal when the object is at rest (unstressed state). Once recorded, the hologram is readout and the object is stressed. The CCD camera of the holographic system then simultaneously captures two images. The first one is light diffracted by the PRC and is the replica of the unstressed object while the second is directly the current image of the stressed object. Both these images interfere, giving rise to an interferogram which shows the surface behaviour of the object. Local variations of the object response reveal particular local behaviour that may result from the presence of defects (Thizy, Georges, Lemaire, Stockman, Doyle, 2006).

### 3. EXPERIMENTAL METHODOLOGY

The common methodology for data retrieval by using the above mentioned techniques is to generate a transient sequence of comparatively minute displaced object point positions which

can be effectively recorded with the optical metrology instrument in use. The plethora of the object point positions makes fringe patterns from defected regions and each fringe pattern relatively different re-arrangements as compared to previous one to be surely and adequately visualised. Thus each defect is retrieved and recorded with its dynamics of deformation and a databank of fringe patterns representing each traced defect is secured. In checking the same defect in any later times is simplified by the databank retrieval mechanism which can identify the defect in various fringe pattern shapes. This is a very important feature of IAP since defects are tend to deteriorate and thus fringe patterns are not steady over time.

Experimental conditions to be satisfied : 1) Uniform excitation, 2) Excitation (thermal IR lamps) time of 10 sec controlled via the PC, 3) Laser power of about 250 mW, 4) Holographic camera on tripods, 5) Environmental condition monitoring.

The measurement procedure and the IAP development take into account other specific parameters of the experimental system and components effects, such as: a) Determine the type of defects that can be studied using the sensors, b) Sample holder evaluation, c) Excitation power evaluation, d) Excitation position evaluation, e) Investigation of known defect size, f) Repeatability study, g) Reproducibility study, h) Sensor performance – *steady defects*, i) Sensor performance – *unsteady defects*.

## 4. RESULTS

### 4.1 Exemplary signatures of defect classes for IAP development

Representative fringe patterns can be generated from a variety of structural discontinuities being natural e.g. wood knot, or artificial e.g. nail, or degenerated effect e.g. detachment. The critical aspect in the IAP implementation is the initial discrimination of type of defect termed here stable and unstable which allows isolating each of the variety of fringe pattern keeping its origin of cause; which determines the expected dynamical range of change. Hence, by keeping data of fringe patterns generated by an unstable flaw such as a detachment; the fringe pattern may change considerably, whereas by a steady discontinuity, as a knot, a steady reference area of discontinuous fringe pattern is always expected and an identification mapping is possible at any later instance even if appearance of some discontinuities have changed. Further on the same databank can be used to assess the Impact that has been provoked to an artwork either positively e.g. consolidation of detachment or negatively e.g. expansion of detachment.

In the following example a sample simulating a Byzantine icon with stable and unstable defects purposefully induced for the aim of the experiments has been constructed by the specialist conservator, shown in Figure 2a-d. Inspection and isolation of defects has been achieved and a databank of artwork features or “signatures” has been obtained. Further on the project foresees cycling of the sample under controlled conditioning according to conservation protocols which will allow enriching the databank with potential fringe patterns.

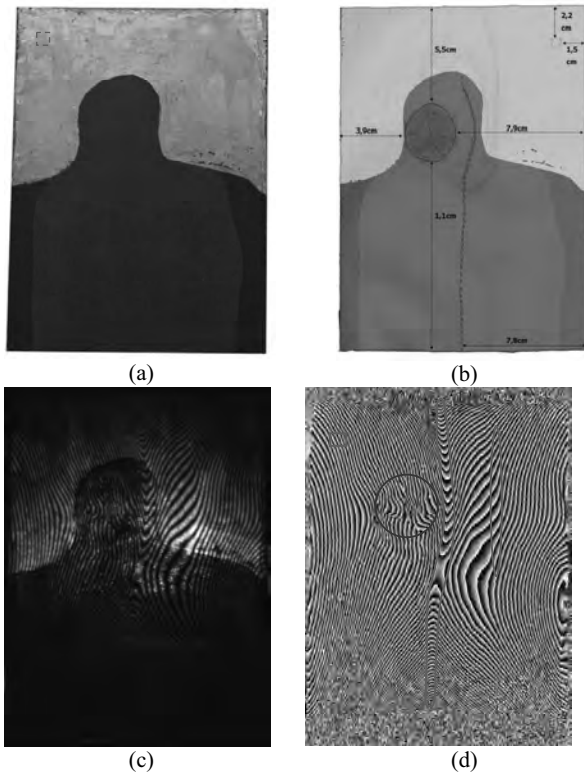


Figure 2 (a-d): In a) The photo of icon sample, in b) the topographic map, in c) a PRC holographic interferogram and in d) the extraction of fringe pattern from which defect isolation is performed (blue: stable, red:unstable).

The experimental methodology is designed in order to verify use of the elements extracted of raw interferometric data thus the *density* and *defect data* as signatures which can witness alterations. Given that movable artworks undergo controlled or random condition changes according their display, storage, handling and transport is assumed that both *density* and *defect signature* may show alterations over time. The experimental objective is a feasibility study clearly proving that the selected signatures remain signatures over time. Signatures measurable and comparable to initial entries of raw and analysed data are collected under various experimental settings, thus excitation time, interval between consequent exposures, load type, value and direction. To achieve the experimental objective the experimental methodology implies stimulated conditions corresponding to a) environmental cycling and/or b) ageing; with specific conservation protocols. Samples were constructed by specialised conservators including known defects accompanied by detail topographic map and cross sectional composition. The defects are distinguished according to the expected alteration dynamics as mechanically *stable* or *unstable*. A Byzantine icon sample is shown in Figure 3.

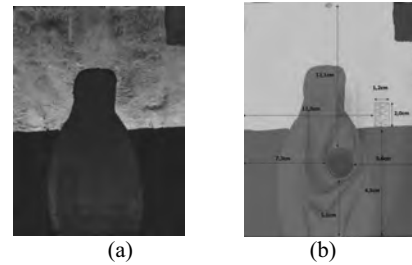


Figure 3: a) Exemplary sample of Byzantine icon, b) topographic visualization of known defects.

The sample is first investigated under controlled parameters to acquire the first set of data and then ageing is induced for the second set. The ageing protocol of this series of samples was Continuous heating at 60°C, for totally 66.5hrs. The aim of this set of load by heat was to provoke deterioration of the wooden structure, omit causing excessive deterioration of structure but affect the size of defects. Figure 4 shows raw interferometric result before and after the ageing.

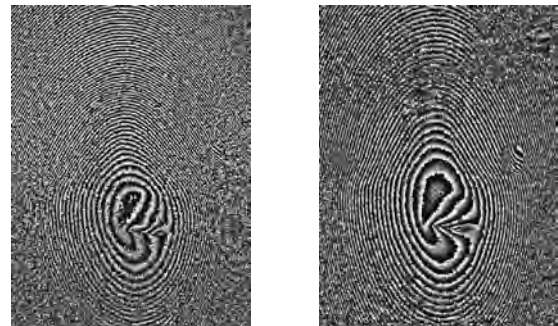


Figure 4: The sample left-before and right-after ageing. Defects act as signatures of the sample and witness the impact of cycling.

Therefore the experimental procedure aims to generate interference data which can be compared to previous or later entries. Technical parameters of the system, detailed description of the artwork under investigation, and raw data are inserted in special windows of the database to support through time the Impact Assessment Procedure. Next time that the same sample is inspected the experimental parameters are reproduced. Any changes of the key-elements consisting the *artwork signatures* are isolated and compared. The chosen experimental parameters in general are not critical for the experimental success but for the aim of future comparison form strict boundary conditions.

In Figure 4 there are seen two dominant defects. Both are traced before and after conditioning. Although the defects are present and their structure remains unchanged the expansion of defect dimensions is outstanding. Similar behaviour was exhibited by most samples under investigation confirming the usefulness of defected fringe patterns to act as multiple information sources. The defect is thus detected as signature of the artwork allowing its characterisation. Identification of authenticity of the sample under concern can be issued and also is quantitatively analysed to identify impact. Defect coordinates and scanned intensity profiles are pc derived and held in the database. An example of intensity profiles before and after ageing is shown in Figure 5 and some chosen positions are selected for comparison.

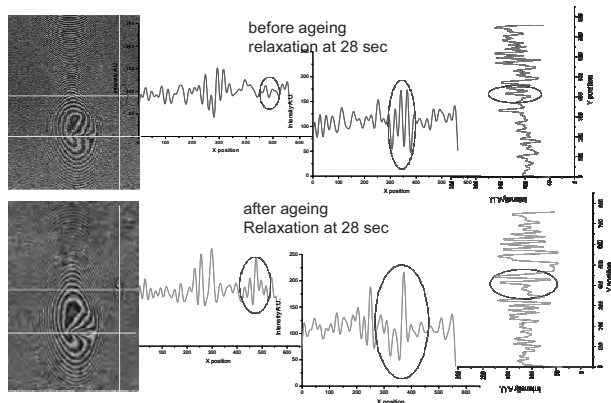


Figure 5: Example of sample shown in figure 4 with its scanning to acquire the intensity profiles across x,y and diagonal axes.

The values of the intensity profiles are fed to tables in order to graphically represent the dynamic of sample reaction inside and outside the defected region. Figure 8 shows a graph resulted from measurements of defected and undefected areas. The defected showing higher response witnessed by higher fringe density values. However, in this example defect area exhibits higher density values but this is not a rule for defect exhibition. Defects deep in the bulk can have only minor influence on the surface. Is not the value but the different displacement response the signal of interest.

## 5. CONCLUSIONS

The *feature encoding* project or MultiEncode aims to prove the satisfactory use of fringe patterns as multi-encoding elements witnessing distinct reactions of artwork complex constructions under pre-specified investigation procedure. Many hidden defects may succeed to affect the surface and generate a discontinuity in an otherwise homogeneous response. Despite such complex structure the distinct response of each artwork can be retrieved and used as a unique identification to witness either structural impact or authentication. The fringe density and the fringe pattern formation used as direct signatures can be compared at any time to deliver indication of impact or fraud. The project develops successfully and the developed methodology allows accurate measurements from the raw data. Portable instrumentation, post-processing software, dedicated database and user-friendly software are also developed for this unique metrological application. It is first time elaborated in such detail the possibility for a fringe pattern based method capable to allow conservators studying changes in artworks for conservation, restoration, authentication aims.

Generally, the holography and speckle techniques examined are very promising methods and in regards to artwork inspection show good defect traceability. There is no method so far that combines all this pictorial for the state of the artwork structural information. Speckle-based systems (DSS and DSHI) have no or small sensitivity to perturbations. Additionally they both show lower resolution results. Photorefractive dynamic holography (without active phase control) is strongly sensitive to perturbations but shows a very good fringe quality and which makes possible observation of small signatures.

The concept of “signature” of artwork based on its own defect-fringe pattern assembly is a coded operation by nature. It was

indeed seen in the investigation that most of the time, even if is difficult to obtain the same overall fringe pattern, at the same time, the signature stays visible at the same place.

The Impact Assessment procedure can provide a multi-task data source involved in very demanding conservation applications. The consortium expects this development in a more advanced state of the project.

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## 3D MODELING AND SEMANTIC CLASSIFICATION OF ARCHAEOLOGICAL FINDS FOR MANAGEMENT AND VISUALIZATION IN 3D ARCHAEOLOGICAL DATABASES

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**KEY WORDS:** Reality-based 3D modeling, semantics, shape grammar, visualization, 3D database

### ABSTRACT:

The generation of digital 3D models of archaeological finds can be followed by further products, applications and studies such as a semantic classification in order to organize the digitally documented finds and provide connections between 3D models and databases. In this contribution we present a methodology developed to assist the superintendence of archaeological excavations or sites in the digital classification, management and visualization of finds inside advanced database/repository. Our approach, divided in three mutually connected steps (modeling, segmentation and visualization), has been realized as general as possible and tested on different types of archaeological objects. Firstly a reality-based 3D model of a find is produced, using photogrammetry or active sensors. Secondly the geometric model is semi-automatically segmented and classified according to archaeological and architectural rules. The semantic classification of the finds is afterwards linked to an archaeological database to e.g. decide whether the object is constituted by original pieces or some of them belong to other finds and should be re-located. Finally the modeled and classified find is visualized in 3D open-source systems linked to an archaeological database. The visualization of the achieved results (3D models and thematic layers) is thus very useful for monitoring and updating intervention policies within the archaeological area.

### 1. INTRODUCTION

In archaeology the systematic and well-judged use of 3D information for documentation and conservation is a relatively recent innovation, not yet applied on a regular basis as considered too expensive, not really useful and difficult to be linked to classical 2D information. The reason of this lack can be attributed to the perceived 'high cost' of 3D, the difficulties in achieving good 3D models, the perception that this is an 'optional' process of interpretation (an additional 'aesthetic' factor), the difficulty of integrating 3D worlds with other 2D data and documentation and the episodic use of 3D models for scientific analysis.

Nowadays the most common techniques used for 3D documentation are based on image data (Remondino and El-Hakim, 2006) or range data (Bernardini and Rushmeier, 2002; Blais, 2004). Both approaches, often combined (El-Hakim et al., 2008), have their own advantages and disadvantages and generally the choice between them is made according to the budget, project size, required degree of detail, surface characteristics, objectives and experience of the working team. Once a 3D digital model is produced, many further products and studies can be led. Besides visualization, VR, physical replicas, the recovered digital 3D data can be used to rebuild the original architectural layout of archaeological sites and / or programme intervention policies. Furthermore 3D geometry can be segmented, classified and linked to databases (Attene et al., 2007).

In this contribution we present our work and methodology developed to assist the superintendence of archaeological excavations and heritage sites in the digital reconstruction, classification, management and visualization of finds inside advance 3D repositories. The problem required a solution able to provide segmented and classified 3D models which could be

interfaced and linked to archaeological databases and GIS. Our approach, divided in three and mutually connected steps (modeling, segmentation and visualization), has been realized as general as possible and tested on different archaeological objects.

### 2. THE DEVELOPED METHODOLOGY

The generation of 3D models of heritages and archaeological finds is receiving more and more attention in the last years. In which way we can fully exploit and correctly use the recovered 3D information for archaeological purposes is still under discussion and evaluation. But motivated by the practical need of archaeologists to classify, document and retrieve historical and architectural information of finds, we developed a system to assist archaeologists in the digital classification, management and visualization of finds inside 3D GIS linked to existing databases. The method (i) produces reality-based photo-realistic 3D models, (ii) classifies them in layers and (iii) assigns to each element archaeological and architectural information beside the already known geometric properties (Figure 1).

Therefore 3D structures are broken down into their component parts (e.g. capital, shaft, base, etc.) following basic libraries of geometric primitives and then associated to information extracted from existing databases. Each part of the find is then connected to series of information created to ease the retrieval process (on a web-based interface) in a semantics-based context. Our goal is also to improve the retrieval of 3D objects and related information within a repository by annotating each shape not only as a whole, but also in terms of its meaningful subparts, their attributes and their relations. Therefore the possibility to semantically annotate shape parts may have a relevant impact in several domains, like archaeology.

The developed methodology is based on the concept of 3D information organization using semantics and it follows the shape grammar concept introduced by Stiny and Mitchell (1978) and Stiny (1975, 1980). The original formulation of the shape grammar concept operates directly on an arrangement of labeled lines and points. However, the derivation is intrinsically complex and usually done manually, or by computer, with a human deciding on the rules to apply.

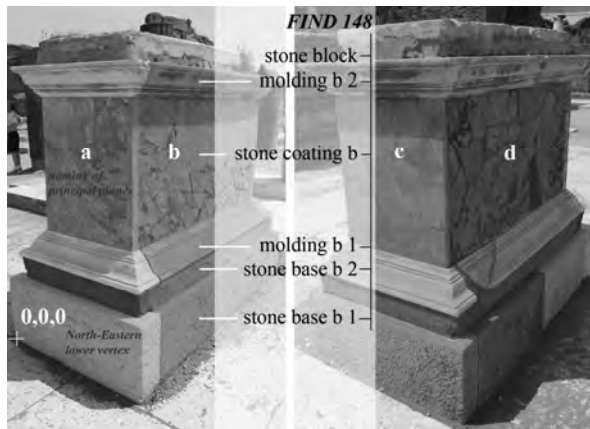


Figure 1: Example of geo-location, reference system, identification and naming of single elements and groups constituting a particular archaeological find.

### 2.1 Related works on modeling and semantic

The first example of 3D modeling and semantic classification was presented in Quintrand et al. (1985). The authors clearly state that to associate semantics to an architectural shape requires to regard the building as a system of knowledge, then to extract a model from its description and finally to define its representation according to the objectives of the analysis.

Afterwards several researches concentrated on the development of classifications of architectural elements in theoretical frameworks (Tzonis and Lefàivre, 1986) or in applications of the geometrical modeling (Gaiani, 1999). De Luca et al. (2007) presented a methodological approach to the semantic description of architectural elements based both on theoretical reflections and research experiences. Attene et al. (2007) developed the ShapeAnnotator, a modular system to load a 3D triangular surface mesh (and its domain ontology), define the meaningful shape parts, annotate them properly and save the result in a database. For the shape parts definition, they used an approach able to automatically select the most suitable primitive to approximate a set of triangles in a cluster. Semantic modeling and classification has been also used in city modeling applications (Emgard and Zlatanova, 2008). Recently semantic classification was also used as pre-step for a successive procedural modeling of architectures (Mueller et al., 2006).

## 3. REALITY-BASED 3D MODELING

The generation of reality-based 3D models of objects and sites is generally performed by means of image-base techniques or active sensors, depending on the surface characteristics, required accuracy, object dimensions and location, project's budget, working team experience, etc. Active sensors (Blais, 2004) provide directly 3D data and combined with color

information, either from the sensor itself or from a digital camera, can capture relatively accurate geometric details. Active sensors are still costly, usually bulky, with limited flexibility, not easy to be use everywhere or at every time and affected by surface properties. Nevertheless they have reached a maturity since some years and the range-based modeling pipeline (Bernardini and Rushmeier, 2002) is nowadays quite straightforward and supported by many commercial packages, although problems generally arise in case of huge data sets.

On the other hand, image-based methods (Remondino and El-Hakim, 2006) require a mathematical formulation (perspective or projective geometry) to transform two-dimensional image measurements into 3D coordinates. Images contain all the useful information to derive geometry and texture for a 3D modeling application. But the reconstruction of detailed, accurate and photo-realistic 3D models from images is still a difficult task, in particular for large and complex sites and if uncalibrated or widely separated images are used.

Besides range- and image-data, surveying information is also generally combined for correct geo-referencing and scaling. Although many methodologies and sensors are available, nowadays to achieve a good and realistic 3D model, that contains the required level of detail, the better way is still the combination of different modeling techniques. In fact, as a single technique is not yet able to give satisfactory results in all situations, concerning high geometric accuracy, portability, automation, photo-realism and low costs as well as flexibility and efficiency, image and range data are generally combined to fully exploit the intrinsic potentialities of each approach (Stumpf et al., 2003; El-Hakim et al., 2004; Lambers et al., 2007; El-Hakim et al., 2008).

### 3.1 Image-based reconstruction

Accurate and detailed 3D models can be created using photogrammetry. Semi-automated measurements (Figure 2) are generally preferred although the latest developments in automated and dense image matching are promising (Remondino et al., 2008). Generally some manual interaction on architectural features is still mandatory when precision and reliability are the first priority of the work.



Figure 2: Texturized 3D models based on photogrammetry.

Using photogrammetry, the required level of detail can be obtained defining the correct number of surfaces in which the entire volume can be fragmented. Particular attention has to be paid to silhouettes and deteriorated corners.

The derived geometric model is then textured for photorealistic visualisation (Figure 3). In order to add more detail to geometry (where the model does not require the same accuracy), the manipulation of textures, for example by means of bump mapping, can also help in simulating relief and irregularities.

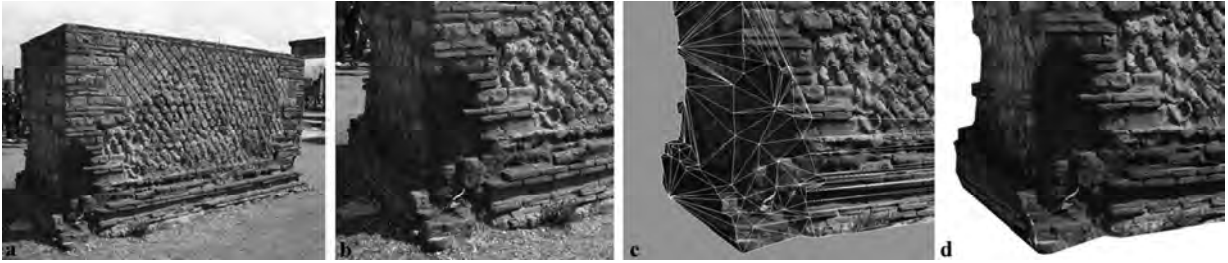


Figure 3: Reality-based 3D modeling and generation of the desired level of detail of deteriorated corners. (a, b): images of the find and closer view of a deteriorated corner. (c): 3D geometry rebuilt using photogrammetry. (d): textured 3D model.

### 3.2 Range-based reconstruction

Accurate digital 3D models of archaeological finds can also be created using range-based active systems (triangulation-based or ToF laser scanners, pattern projection systems, etc). This surveying and modeling approach implies the use of costly instruments which are in any case widely used within the architectural and archaeological field.

The use of range sensors involves planning and knowledge about the accuracy and quickness of measurements, costs, surface properties, object location, etc as well as good experience of the working and modeling team.

We employed both triangulation-based and ToF scanners to survey and model some finds. The obtained point clouds were registered, meshed and the 3D models textured for photorealistic visualization. Then, like in the image-based case, our work continued with the segmentation phase (Section 4) and the linking to the database. For some models (e.g. Figure 6) additional surfaces have been introduced in order to rebuild hidden volumes and clearly separate the different architectural elements.

## 4. FINDS SEGMENTATION

This operation requires the help and support of archaeologists and architects to recognize transitions between different elements that constitute the find and semi-automatically segment it. The semantic classification of the finds is used in the archaeological database to decide whether the object is constituted by original pieces or some of them belong to other finds and should be re-located. Furthermore, the semantic classification of the finds leads to the identification of classical orders, building functions and materials as well as extra information. The semantic segmentation is done directly on the 3D geometry using a supervised classification. Additional information such as geo-location and numbering are also added in order to uniquely indicate a single element within the entire set of finds (Figures 5, 6, 7 and 8).

Each part is connected to an instance in a knowledge base to ease the retrieval process in a semantics-based context. The naming of each single element and of the classes in which they can be grouped is an important process that strictly depends on archaeological and architectural considerations.

Assuming that each single element has to be considered regardless of the context in which it is located, the name can be derived from classical orders only if specific morphological analysis can be led, otherwise, the name has to suggest building function or building material that guarantees more

general and versatile interpretations. The segmentation of a find in its single components follows the 3D modeling phase. For models obtained using range data, due to the large number of triangles, it is not possible to automatically recognise the transition among different elements – especially when their surfaces are coplanar or have similar finishing characteristics. On the other hand, for 3D models obtained using image data, the search of borders and transitions among elements could be done during the modeling phase, by detecting homologous points and curves on the different images. But this approach could increase the error while orienting the photographs and consequently reduce the metric accuracy of the 3D representation. For these reasons the segmentation is done using a 3D modeling software, after having built the geometry of the whole find (Figure 4).

The mesh is segmented using instruments that can sub-divide single triangles following the transition profile that can be visually recognized using the texture or surface irregularities.

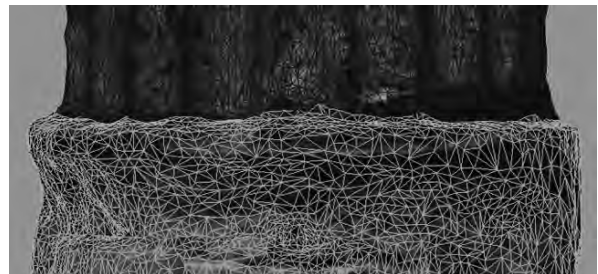


Figure 4: Segmentation of the whole geometry of the model by recognizing the transition among different elements with the help of texture and surface irregularities.

While the mesh is subdivided and the model segmented, the semantic structure of the find suggests the organization of single nodes and their naming (Figure 9). After the segmentation phase, it is possible to re-build inner subdivision surfaces, in order to define the entire volume of each single element and node. This phase is strictly dependent on the ability of archaeologists to recognize morphological elements and constructive techniques and give volumetric interpretations.

In order to differentiate metric reconstructions from volumetric interpretations, it is necessary to use bright colors (for example bright red or yellow) that can easily be distinguished from other textures.

In order to estimate the costs of these operations in terms of time, for finds that have a middle complexity (as the ones that are shown in the images of this paper), the segmentation and inner re-build of volumes usually requires one man-day per piece.

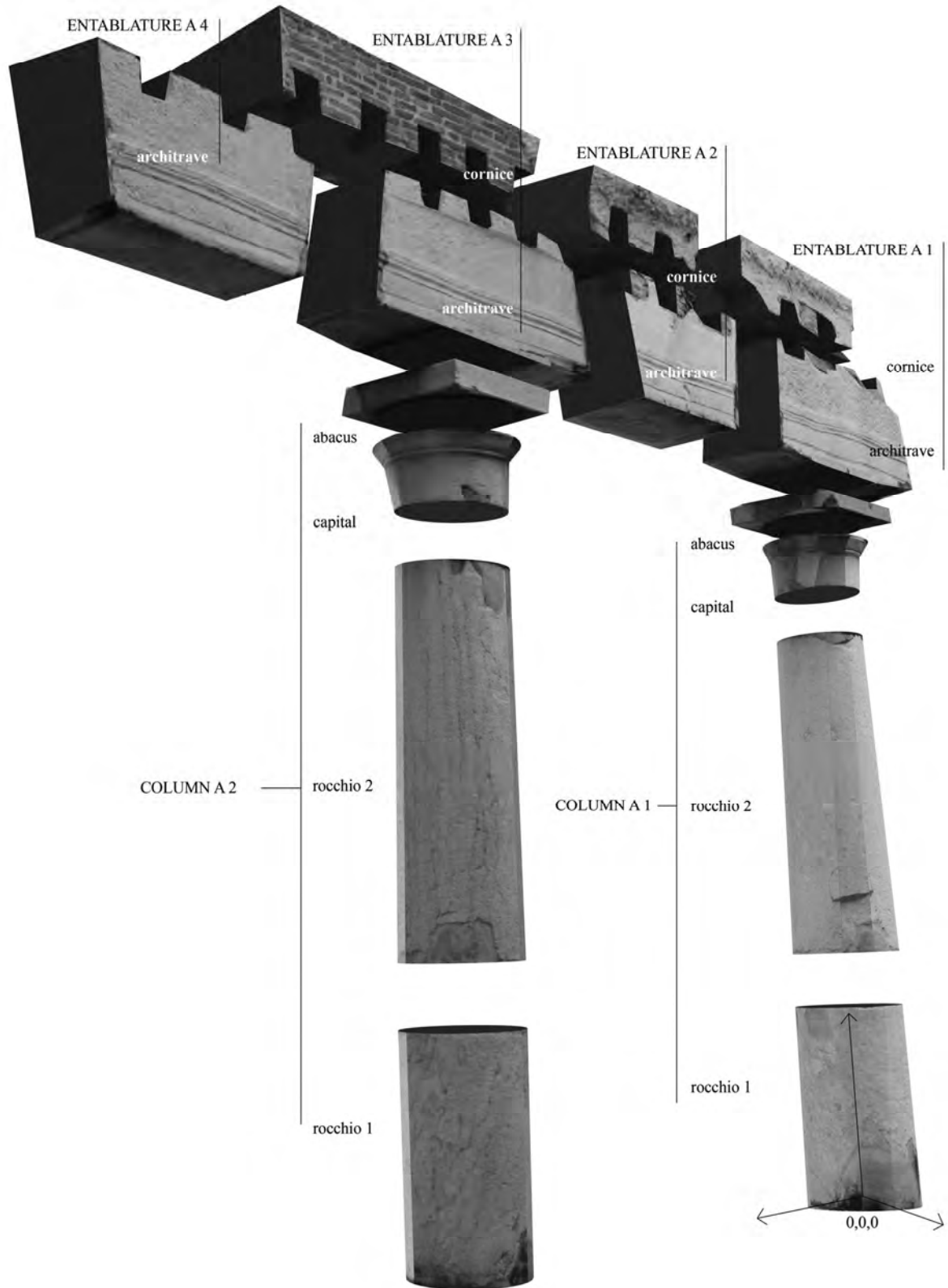


Figure 5: The segmentation process of the reconstructed 3D model, consisting of (i) identification of single elements, (ii) naming of the elements, (iii) identification of relations between them and (iv) definition of the volumes they subtend. All this information is stored in a database together with find's number, geo-location and other useful archaeological details.

## 5. VISUALIZATION AND GIS FUNCTIONALITIES

The survey of archaeological finds involves 3-dimensional considerations. Traditional 2-dimensional representations (such as orthogonal projections) do not constitute the right method to represent digital measurements, investigations and prepare protection policies, restoration interventions, etc.

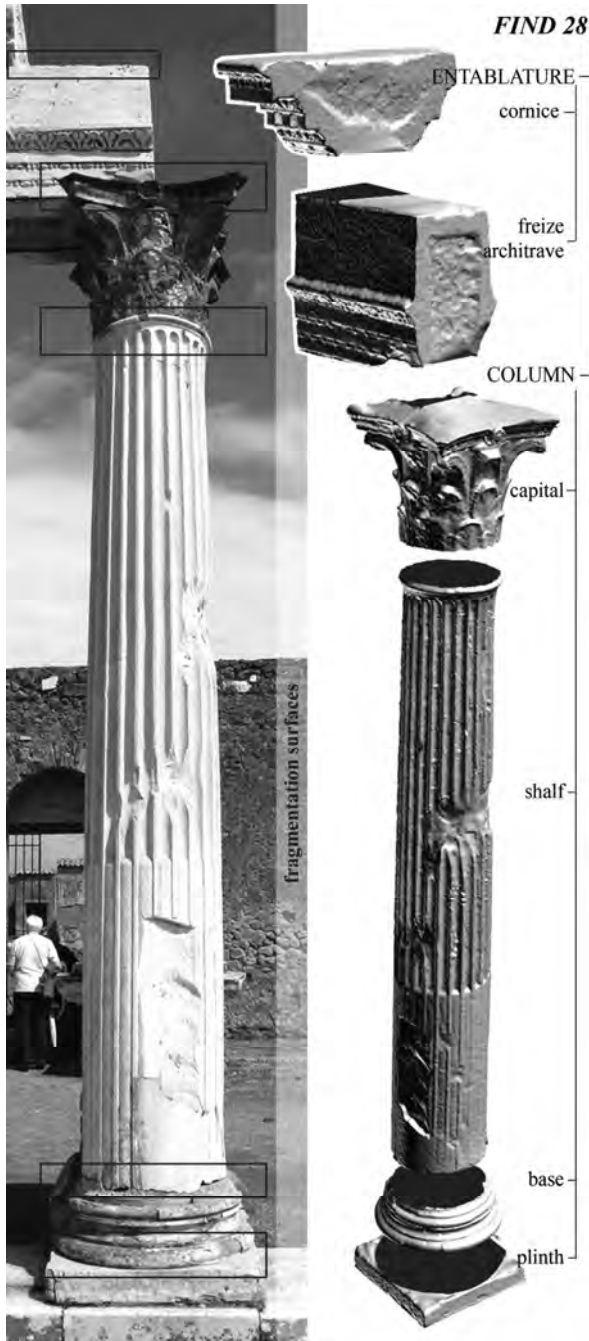


Figure 6: Left: recognition of discontinuities and identification of single elements. Right: segmentation and semantic organization of the fragmented 3D model. Additional surfaces (red areas) have been introduced in order to rebuild hidden volumes.

In order to preserve the 3rd dimension, survey data need to be represented, organized and managed using advanced repository of geometrical components. Those packages allow visualization, interaction with digital models and database queries.

This is not an easy problem, because current real-time systems have been planned for visualization, but not for non-expert interaction. To be considered a “3D repository”, a system must be capable of handling data as more than a surface. It must handle geographical feature data, support query processing and spatial analysis in addition to dynamic user interaction according to three classes:

- orientation and navigation;
- selection and query;
- manipulation and analysis.

In the developed methodology, textured 3D models, obtained using photogrammetry or active sensors and semantically segmented and classified, are displayed and queried using a rendering application based upon OpenSceneGraph (OSG). The OpenSceneGraph is an open-source high performance 3D graphics toolkit, used by application developers in fields such as animation, visual simulation, gaming, virtual reality, scientific visualization and modeling.



Figure 7: Example of segmentation and classification of the digitally modeled elements that constitute an archaeological find. The naming of single elements and classes they can be assembled to depends on considerations about the recognition of classical order rules, or building functions or materials. Extra information such as geo-location and object number can also be added.

Written entirely in standard C++ and OpenGL, it runs on all Windows platforms, OSX, GNU/Linux, IRIX, Solaris, HP-Ux, AIX and FreeBSD operating systems. Unlike other open-source solutions, such as VRML (Virtual Reality Modeling Language), for example, OpenSceneGraph allows to use OpenGL instruments not only to manage geometry, but also to correctly visualize texture and illuminate digital models. Using shaders that can be managed by common hardware (GPU of video board), these instruments are very useful in order to give much realism to 3D models. For example, some image-based models



were textured using normal maps that don't modify the recovered geometry, but simply improve the visual appearance of the rendered surfaces by simulating small irregularities. OSG better supports the bump mapping approach than other visualization toolkits do. Anyway bump and normal maps were used only in cases where geometric irregularities were below a determined threshold, in order to precisely model the find but also visualize the small irregularities.

In addition to OpenGL instruments, OSG allows to customize the visualization of digital documentation. For our methodology, we have adopted the VISMAN visualization system, a version of OSG realized by CINECA (Inter University Consortium), in order to support the visualization of architectural and archaeological semantically segmented 3D models linked to external databases. Indeed the VISMAN framework allows to:

1. switch between models with different level of detail or pertaining to different historical periods but insisting over the same area;
2. insert IBR (Image Based Rendering) geometries;
3. add parts to the model (i.e. addition of sections built through the centuries);
4. connect to a relational multimedia database.

The latest feature has been a key point in the development, allowing the user to display dynamic content containing detailed data connected to a specific object in the scene. This connection is defined using a naming convention. Objects inside the nodes of the scene graph are given a specific prefix and a unique number. When the user interacts by clicking or passing the cursor over an object, an SQL query is performed and a pop-up window is used to show the retrieved data.

VISMAN is available as a standalone software, as well as a web browser plug-in.

In our methodology, semantic segmentation has been used to link huge data not only with archaeological finds, but also with their single sub-parts. The connection between the database and the single parts of an archaeological find upgrades the traditional 2D GIS to a 3D system. Digital models are geo-referenced (by point, line or area belonging to necessities), so that they also can be linked to 2D systems that are generally already available.

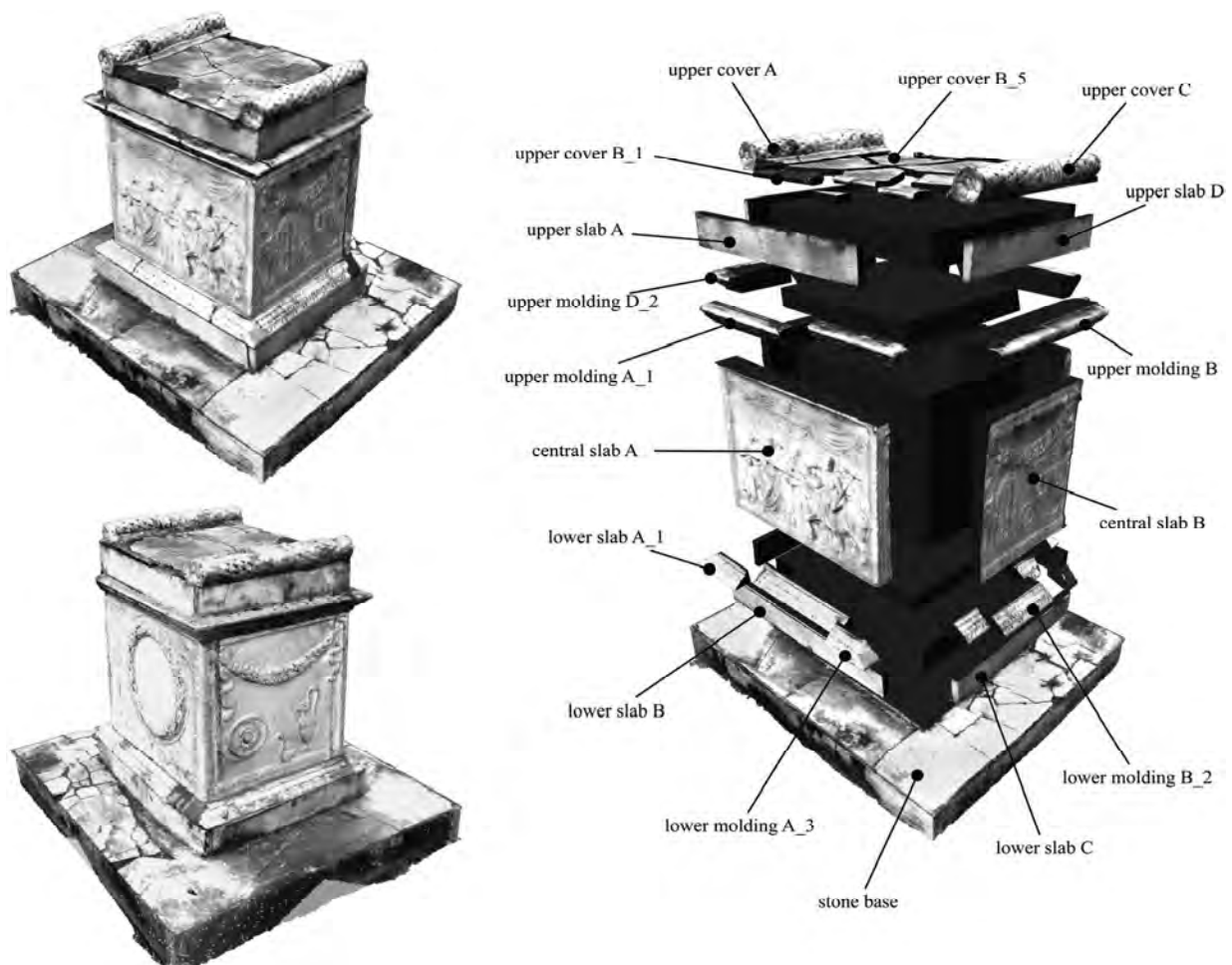


Figure 8: A range-based 3D model of an archaeological find (left) and the segmentation and definition of its sub parts (right). The linking to the archaeological database is done in a successive phase and queries can be done through a web-based interface.

Semantic fragmentation allows archaeologists to study every single element without context. This facilitates the recognition of wrong assembly. Furthermore, this classification is a useful instrument for the excavation administration that permits to check the consistency of the archaeological heritage and to program restoration and conservation interventions.

The link between 3D models and 2D documentation is bi-directional, so that it is possible to access data from models and vice-versa, using the same web based interface (**Figure 10**).

The system can therefore be easily linked with any kind of database available on web. The 3D advanced archaeological database has been conceived for different uses and a LOD technique is also implemented. Different LODs guarantee the maximum quality while observing finds that are near the observer, but also allow faster visualization of large finds, with a more effective use of resources.

## 6. CONSIDERATIONS AND CONCLUSIONS

In this work we presented how engineers and architects can contribute in the archaeological documentation and classification of finds and excavation sites with the current 3D modeling technologies and methodologies. The use of digital instruments to survey and represent 3D models requires abilities that often belong to the background of engineers and architects.

On the other hand, the organization of data has to be led of course with the help and support of archaeologists and superintendences that can lead historical and archaeological analysis upon sites.

The large use of digital instruments to provide photorealistic 3D representations and to manage huge documentation requires that more and more interaction between the different communities involved in the heritage field must be reached and each specialist must do his/her job and deliver to others duties which are not in his/her background.

Our work has been led testing different technologies upon different kinds of finds, in order to supply accurate digital 3D models of archaeological objects. These tests have pointed out that nowadays a combined use of different technologies has to be adopted, in order to give satisfactory results in terms of metric accuracy, photo-realism, portability and reduced costs.

Semantic classification of archaeological finds is necessary in order to organize huge amount of documentation and to provide connections between models and data.

Future prospects could be singled out in the definition of standards for the creation of advanced 3D databases and the definition of precise roles of different working teams involved in this process.

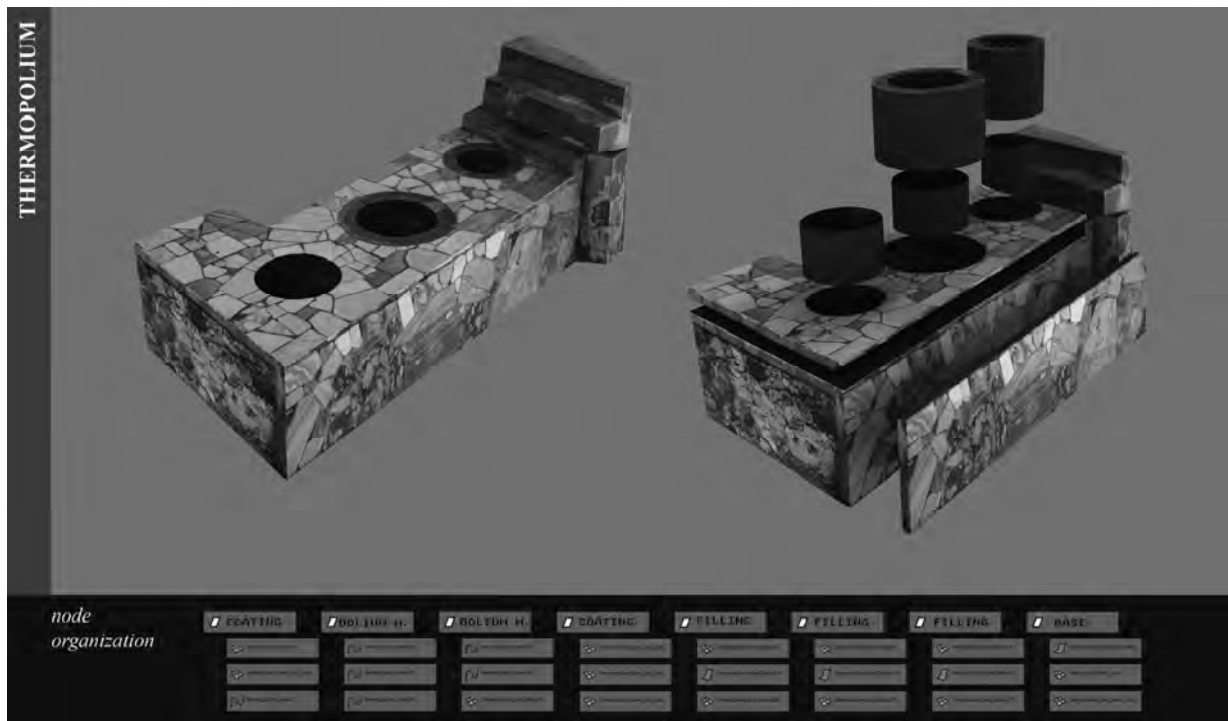


Figure 9: Segmentation example of 3D image-based models and the definition of sub parts linked to the archaeological database.

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Figure 10: Web interface of the advanced 3D archaeological repository. The fragmented 3D model represents an access to large kind of information stored in the archaeological database. The link between 3D models and database is bi-directional, therefore information can be retrieved selecting a part on the 3D model or accessing the database, but using the same web-based interface.

## STANDARDS AND GUIDELINES FOR QUALITY DIGITAL CULTURAL THREE-DIMENSIONAL CONTENT CREATION

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**KEY WORDS:** Standards; Documentation; Digitization guidelines; 3D scanning; 3D modeling; MINERVA; EPOCH

### ABSTRACT:

Due to progress in the development of digital 3D graphics and visualization tools, both HW and SW, and to the decrease of their cost, it is easy to foresee a short-term substantial increase of 3D digitization initiatives by cultural institutions. The paper introduces a recent initiative launched by the EC eContent funded project MINERVAeC, targeted to provide guidance to medium and small cultural institutions wishing to undertake 3D scanning or 3D modeling of objects or scenes of cultural interest, and/or wishing to make three-dimensional digital resources accessible through their institutional websites. Building upon the experience achieved by the EPOCH project (European Network of Excellence in Open Cultural Heritage) and upon the successful results of the previous MINERVA (Ministerial Network for Valorizing Activities in Digitization) activity in the field of quality of cultural websites and of guidelines and standards for interoperability, accessibility and long-term preservation of the digital resources, an expert group is currently drafting a set of guidelines aiming at:

- Identify standards and guidelines for planning, designing, carrying out, documenting, publishing and communicating multimedia 3D projects and resources;
- Underline the importance of documenting the 3D digitization process and its results;
- Foster synergies, avoid duplication of efforts.

At the same time, a census of the 3D realizations of cultural interest is being carried on, and good practices will be identified among the collected resources in order to propose them as references, thus complementing the guidelines.

### 1. INTRODUCTION

The adoption of ITC for 3D reconstructions is now recognized as a fundamental element of any cultural communication strategy and thus included by cultural heritage professionals in their projects.

Recent progress in the development of digital 3D graphics and visualization tools, both hardware and software tools, made that the creation of digital 3D models is now both economically accessible and easily manageable without the need for demanding training. This begins to draw up technology developers to end-users in a considerable way.

The change of the cultural approach raised significantly the quality and the scientific reliability of the 3D reconstruction. On the other hand, the break up of new protagonists, modelers and creators of 3D reproductions of architectures, landscapes, monuments and excavations, produced an important increase in the number of 3D models.

The simplifying of products and solutions for 3D data-acquisition and rendering of 3D digital objects moved the focus of the application from the exhibition of the power of computer graphics to the quality of details, from the graphical engine and rendering processor to the particular of the reconstruction; even minimal features of the environment are now carefully analyzed.

The extreme care in implementing 3D reconstructions is the final result of a new attention paid by the stakeholders to the communication capability of ICT, both as for the large audience and the narrow scientific community. Besides the traditional instruments for the survey and the 3D modeling, now are

available complex equipments as the 3D Laserscanner; this device allows to gather in a short time complete 3D data (objects and landscapes) and sophisticated elaborations of graphical rendering.

It is easy to foreseen that in the near cultural institutions will take advantage of the equipments for 3d data acquisition, thus producing an increase of the digital 3D multimedia resources, available online or offline.

3D virtual reconstructions, interactive and/or static, are very easy to produce nowadays, and this raises some issues mainly concerning the definition of the procedures and the standards to be adopted for their design and creation, as well as the access and the reuse of 3D digital sources.

Whereas the large cultural bodies, having human and financial resources at their disposal, will be able to investigate these issues carefully in order to find the solutions most appropriate to their needs, small and medium-sized institutions (public or private) are likely to be only partially able to take advantages from the simplification of technical procedures of acquisition and restitution of 3D digital content.

The disparity between larger and medium-small sized institutions in terms of human and financial resources doesn't tend to be reducing, and in the near future this will bring, in the average, to an increase of the gap in terms of specialized competences and expertise. More and more it is therefore needed to provide the institutions with a guidance to acquisition, modeling and long term preservation of 3D data, building upon good practice experience and targeted to allow them to make the most of the opportunities offered by the

technological developments, while avoiding waste of time and resources and time and fragmentation of effort.

In this framework takes place the initiative to set up a working group of the European project MINERVAeC, in order to establish an interdisciplinary cooperation targeted to the provision of 3D guidelines for the use of the cultural institutions, building on the synergy among two major European projects in the field of digital technologies applied to cultural heritage, EPOCH and MINERVA.

## 2. MINERVA AND EPOCH

MINERVA eC is a Thematic Network funded by the European Commission in the frame of the eContent Plus Programme. The project is based on the successful results of the previous MINERVA and MINERVA Plus projects, funded by the 5<sup>th</sup> and 6<sup>th</sup> FP, and is aimed to progress on the same key topics, related to the digitisation of cultural heritage, namely, interoperability and standards, multilingualism, IPR, quality of cultural websites. MINERVA eC operates through the coordination of national policies, programmes and institutions of the cultural sector with the aim to improve awareness of the state-of-the-art in the sector and to create a platform of recommendations and guidelines, agreed at European level.

The set of agreed guidelines, recommendations and standards, developed over the past 5 years and still under improvements, contributes to overcome fragmentation and duplication in digitisation and waste of resources, while maximising synergies among projects, programmes, services.

MINERVA eC is implemented by a network of Ministries and other main institutions in charge of cultural policy, coordinated by the team hosted by the Italian Ministry Of Cultural Heritage and Activities.

One main activity line of MINERVA projects is targeted to provide guidance on the creation, use and management of cultural content by fostering the understanding and the adoption of standards. The main outcome so far were the *Technical Guidelines for Digital Cultural Content Creation Programmes*, a document developed in cooperation with UKOLN and targeted to people in charge of programmes for the creation of digital cultural content, to whom they propose the adoption of standards as the foundation for interoperability and support for access, preservation, security of the digital resources.

The Technical Guidelines are not intended to be a prescriptive set of requirements, but on the contrary, they try to identify Areas where there is already a broad agreement in the practice, and can be flexibly used, as a core around which each project might building context-specific requirements. Edited for the first time in 2004, the circulation of the document proved to be much higher than foreseen; it was translated in several languages and downloaded from MINERVA website more than 30.000 times, demonstrating that it resulted useful to a much wider audience than the foreseen target. Moreover, the Technical Guidelines are being implemented by several programmes across Europe, and as a matter of fact nowadays represent the foundation of the main cultural portal projects, currently developed in several European countries.

MINERVAeC is developing an updated version of the Technical Guidelines, which will support, among other, the implementation of the European Digital Library.

The initiative undertaken by the Italian MINERVAeC working group, of drafting a set of Guidelines on 3D and virtual reality, aims at complementing the Technical Guidelines going more in depth in the field of standards and methods for acquisition, storage and visual display of digital three-dimensional models for objects or scenes of cultural interest.

EPOCH, an EC FP6 funded Network of Excellence, run until end of March 2008, which gathered about a hundred cultural institutions joining their efforts in order to improve the quality and effectiveness of the use of Information and Communication Technology for Cultural Heritage. The consortium included university departments, research centers, heritage institutions, and private companies, together endeavoring to overcome the fragmentation of current research in this field.

The overall objective of the network was to provide a clear organizational and disciplinary framework for increasing the effectiveness of interdisciplinary work through the interaction between technology and the cultural heritage, in favor of human experience represented in monuments, sites and museums. This framework encompassed all the various work processes and flows of information from archaeological discovery to education and dissemination.

The network's primary goal was to encourage all groups to work on problems which have potentially sustainable practical applications in achieving technical objectives, underpinning sustainable businesses and effectively communicating cultural heritage.

## 3. TECHNOLOGIES FOR CULTURAL 3D RECONSTRUCTIONS

In the last fifteen years we assisted to the explosion of technologies and equipments for 3D reconstruction. This increase hasn't produced a proportional discussion about practical and methodological scenarios determined by this new approach to the 3D techniques.

We have a rich bibliography on the technical specifications of the new devices or a deep evaluation on theoretical issues concerning the archaeological virtual landscapes. Nevertheless poor attention has been devoted to the definition of procedural and methodological aspects incorporated in the creation of 3D digital objects.

The debate was developed within different and strictly separated circles: on the one hand, computer scientists and engineers, and to the other hand archaeologists and cultural heritage professionals. The former concentrated on the potential of the technology developing in the computer graphics field; the latter interested mainly in understanding the differences between traditional and digital approach to the virtual reconstructions.

For a long time the growth of the solutions becoming available for the hardware (EDM, GPS, Photogrammetry, Laserscanner3D) and for the software hasn't been accompanied by an adequate evaluation of the reached outcomes. A good reconstruction was weighted for its strong emotional impact or for its interactive and navigable functions rather than for its scientific reliability and trustworthiness. We have hundreds of 3D reconstructions of the most famous ancient sites and for the archaeological areas of greater touristic impact.

As a consequence, such products targeted to a very large audience generated an attitude of scarce attention and mistrust by the archaeologist and professionals towards 3D technologies. In fact, the researches didn't evaluate correctly the added value determined by the availability of 3D object.

Recently, thanks to a more direct participation of the archaeologists in the process of reconstruction of virtual environments, we assist to a resolute turnabout. The researchers evaluate now carefully the procedures adopted for the 3D modeling and not only the visual impact.

This trend extended the diffusion of 3D acquisition and modeling practices, raising new interdisciplinary issues: computer scientists and engineers are now attentive to the more rigorous definition of the parameters essential for accurate 3D reconstructions, and the archaeologists wish to include the three-dimensionality in traditional and institutional practices for the graphical documentation of cultural objects.

A new approach derived from the cooperation between technology and archaeology, that not only highlights the technology and the theory embedded in the models, but is also interested in the methodology incorporated in the 3D reconstructions. From this point of view, the different solutions chosen for a 3D model may become part of a larger operational and methodological pipeline including also the software and the hardware adopted.

Today many diverse technical solutions are available for the creation of 3D models; this raises several problems as for the compatibility and the integration of the generated models and the costs for the production of the 3D reconstructions.

Moreover, the same 3D concept has been used to cover experiences very different from each other, including the recovery of older graphical documentation where the 3D values weren't measured but only made understandable through the perspective of the drawing.

The need to reuse old plans, sections and maps created before the digital survey technologies were developed, determined the definition of specific protocols according to which the 3D reconstructions, lacking of 3D measured data, is similar to an artistic creation rather than a rigorous geometrical description of the objects.

Within the more generic 3D definition we can identify different kinds of products. Basing on the different acquisition method used in 3D reconstructing, we can define at least four distinct groups:

1. Geometrical Model. All the dimensions, x, y, z are acquired by:

1. Manual measurement;
2. Aerial and terrestrial Photogrammetry;
3. LaserScanner;
4. Total Station and EDM;
5. GPS and DGPS;
6. Structured light;
7. Other (for rotation);

2. Manual Model. Plan/drawing in 2D revised in 3D - without direct measurements - by means of:

1. Extrusion 3D (is a process used to create objects of a fixed cross-sectional profile; this function allows to

draw – automatically – an elevation starting from a plan)

3. Hybrid Model:

1. Plan 2D with only third dimension measured by means of a instrument.

4. Reconstructed Model:

1. Model entirely reconstructed without any measurements.

We can have two different approaches for the acquisition of digital 3D models:

- semi-automatic digitization, or 3D scanning, of real objects (at the small, medium or large scale);
- human-driven modeling of digital 3D representations of real or hypothetical structures.

In the first case, we have accurate instruments to encode reality in digital formats, while in the second case we produce representations which are mediated by the experience and culture of the human operator.

Behind a 3D model are hidden different tasks and technical choices determining approaches and solutions that may result not always transparent. The different approaches and methods in constructing a 3D model clearly appear when researches fail to reuse in different contexts the same 3D object. Besides this, the technical steps for the creation of a 3D resource can be deeply divergent because of the lack of shared protocols and standards; from a single 3D acquisition can be generated very dissimilar reproduction resources.

Not only 3D model types may vary significantly, but also the software used for their creation and for the management of 3D digital data. Some models are processed in a static way and they are used only for the printing; others show a simple or more elaborate interactivity.

The models can be realized using several different formats (open, closed, standard, proprietary), and this makes more complex the re-use of the models if the software that generated them is not available.

The current approach to issues and problems connected to the 3D construction and data processing seems to focus on the adoption of interdisciplinary methods. Although several achievements are emerging both as for the practice and the theoretical elaboration, nevertheless what dramatically emerges is the lack of a clear framework of technical, descriptive, documentation standards, and of protocols, procedures and metadata for 3D objects.

#### 4. MINERVAEC WORKING GROUP

The Working group established in the framework of MINERVAeC project has the task to outline a set of guidelines helping the stakeholders to better understand and select among different solutions for 3D data acquisition and modeling.

Following up the positive experience made by the Italian Interoperability working group, that in 2006 produced the Italian edition of the MINERVA international Technical

Guidelines, MINERVAeC working group is composed by experts and professional belonging to several different domains, in order to gather expertise coming from many different fields and application domains and thus open up a wide spectrum of possible case studies, tested solutions and choices in terms of systems for 3D data handling.

The cultural heritage preservation institutions are represented by the Istituto Centrale per il Restauro (Central Institute for Restoration), the Istituto Centrale per il Catalogo e la Documentazione (Central Institute for Catalogue and Documentation), the Istituto Centrale per il Catalogo Unico delle biblioteche italiane (Central Institute for the Union Catalogue of the Italian Libraries), the Directorate General for the Archives, the Superintendence for Architectural, Archaeological, Artistic Heritage of the province of Pisa, all of them under the Ministry for Cultural Heritage and Activities; the expertise developed by EPOCH is brought to the group by the researchers of the National Research Council – ISTI, the University of Florence and the Inter-Departmental Centre for Archaeological Service of the Orientale University of Naples; two small but highly specialized companies contribute the experience of the private sector committed with the production of quality 3D realizations, while a cross-domain point of view is provided by the participation of the Technology Observatory for the Cultural Heritage and Activities (OTEBAC), MiBAC service developed in cooperation with MINERVA and MICHAEL projects.

Restores, archaeologists, computer scientists, engineers, architects, specialists in the field of ICT for cultural heritage and communication with a long term experience in the field of digital technologies applied to 3D reconstructions have drafted a technical document addressing 3D issues for the Italian cultural institutions.

At the moment of writing, the working group is finalising the first draft of the document. This draft, written in English although most members of the working groups are Italian, will be circulated among MINERVAeC international network of experts, who are expected to give relevant feedback. The first draft release is foreseen on the occasion of MINERVAeC final conference, which will take place at the end of September 2008 Leipzig, Germany.

The work covers both the 3D scanning of physical objects and the 3D modelling (born digital 3D content created with computer graphics systems), for which both it tries to identify and propose standards and guidelines for planning, designing, carrying out, documenting, publishing and communicating multimedia 3D projects and resources.

In the Introduction the document faces the reasons for governing a major technology evolution phase, analyzing progress of digital 3D graphics tools, including: new HW/SW tools for gathering 3D representations of real objects and for the reconstruction of 3D scenes. Besides it includes a forecasted panorama in the near future.

A special emphasis is given to the importance of documentation: on one hand, a quality cultural 3D resources is based on scientifically accurate sources and evidence, on the other hand it is crucial to document every stage of the 3D digitization process and its results.

It was required to the experts to break down the matters taking into account a non-technical audience and to adopt a language as simple as possible. Some issues are addressed at two levels

of depth, with a general introduction for non-specialist readers and a more-in-depth treatment addressed to technical experts.

As do the Technical Guidelines, the 3D guidelines cover the entire life cycle of the digitisation project (objectives and goals, requirements, corresponding technology, budget, human resources and training) and of the digital resources created, emphasizing the archiving, management and preservation of digital data and the maintenance of the digital archives. Attention has been paid to the distinction between the digital master (the original acquisition achieved by means of any digital or optical equipments) and the following revisions and/or reconstructions.

The importance of the adoption of appropriate metadata standards is underlined, and it is highlighted the role of Dublin Core Metadata Initiative. For the description of technical processes it is suggested the use of a specific category of process description metadata, named Paradata.

Paradata are a special class of observational data introduced in order to more precisely determine features of the measuring/capturing of data. They are useful whenever we want to re-use manipulated data, stored in the archives, or to have information about the processes generated. Paradata may be described as a way to check and alter any procedure evaluating costs/benefits in order to optimize the processing.

An attempt to outline a framework of Intellectual property rights related to 3D resources is ongoing. A stronger need for protecting Intellectual Property Rights (IPR) is arising, especially for those involved in the creation of expensive contents, due to several reasons: first of all, in digital technology reproduction costs are very low and computer networks enable the distribution of multimedia content worldwide, cheaply and quickly. As a consequence, it is easier and less expensive both for the rights holder to distribute a work and for an individual user to make and distribute unauthorized copies. Moreover, in the everyday life, users have the capability and the opportunity to access, copy and modify vast amounts of digital information, without a clear knowledge of what is acceptable or legal.

The information provided by the document is complemented with a technical glossary, aimed at clarifying the technical terms possibly not familiar to an average cultural heritage professional.

Once set up the framework, the group will launch a census of 3D realizations with the aim of setting up the scene, fostering synergies between projects and avoiding duplication of efforts.

## 5. CONCLUSIONS

The document faces many different topics trying to give a wide survey of all possible fields of application of 3D data. The choice of a very simple and understandable language is aimed to involve a wider audience starting from easy concepts concerning 3D data-acquisition and processing.

The work cannot replace the role and the functions of the experts or professionals in 3D field, but its scope is to offer to a large audience all the necessary means to understand better 3D models, their carrying out, their evaluation and their exploitation.

We hope that the circulation, among the practitioners, of these technical guidelines could demonstrate the effectiveness of this new technology for 3D data acquisition and processing. Besides archaeologists and curators could easily analyse costs and benefits for each single project and evaluate their carrying out and management. In this way practitioners could coordinate directly their projects paying attention also to the archiving issues and reusing of the 3D data.

In conclusion this document could stimulate a larger application of these new 3D technologies giving to archaeologists and museum curators a more central role in 3D data creation, preserving and maintenance.

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## TOPONYMS AS HORIZONTAL LAYER IN DOCUMENTING AND LISTING CULTURAL ITEMS

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### ABSTRACT:

Toponyms (name places) are indispensable attributes of any cultural artifact, i.e. place of origin, place of use, its pedigree. More importantly toponyms are often declared on the artifact itself. This declaration can appear as ‘printed’ characters, fully or abbreviated, more rarely as symbols (punning allusions). Characters belong to one or several languages, the language of the local population, that of the artifact’s creator, that of his master, etc. Characters can also be expressed in several alphabets, scripts. Limited space competes with correct rendering in terms of direction of writing and aesthetic appearance. Thus toponyms appear ‘correctly’ or misspelled, erroneously or intentionally. Their appearance in daily use artifacts is complex and rich in variations. These are not one-off manifestations destined to an extremely limited circle, but rather real mass communication media, bearing cultural, ethnic, political and religious messages across space and time. Numerous lesser cities and localities are only known from their names appearing on coins and more recently on postal cancellations. Even to this day there are sensitivities of the same nature when attempting to catalogue and present place names featuring on them. This paper proposes a mapping of the time, geographical and ‘linguistic’ dimensions of toponyms into appropriately flexible data structures. It presents a related project dealing with ‘Ottoman Postal Cancellations’. It promotes a horizontal layer offering the association of artifacts to toponym(s) and thus contributes to a commonly agreed and universally applicable procedure for removing ambiguities arising today in documenting and listing cultural items on the basis of its bindings to geographic data.

### 1. INTRODUCTION

Cataloguing of cultural objects usually results into a self contained schema. Emphasis is given to an agreed representation of each item having in mind ease of exchange, combining, editing (CCO, 2006). We deviate from this standard setting in two ways.

We examine collections of instances of the actual cultural items in the form of prints or strikes (postal cancellations, coins). As a rule, the actual templates (cancels, dies) are inaccessible and we can collect and list only incomplete or partial instances thereof.

We are faced with several versions and ambiguities in identifying place names (post offices, coin issuing entities – e.g. cities). These are found on the collected instances and are themselves partially incomplete, partially misspelled renderings of ‘official’ names. Official names in the spirit of (The J. Paul Getty Trust, 2007) cannot be assumed. This would mask out important cultural and linguistic content expressed by different names, spelling, language, script used to express geographical entities. In general a set of such renderings can be found on the actual artifacts and this alludes to a partially agreeing set of name(s) otherwise used for that place at that particular period of time.

This work intends to address these issues in a generic way. In so doing it places emphasis to ‘lightweight’ cultural applications. The application described here and similar ones suggested are for the layman / hobbyist and not necessarily for the specialist. Therefore ease of use, excitement in discovering seemingly small details (e.g. the old name of a place) is a crucial side factor to the main theme (the cataloguing, searching, identifying items of a collection). The ‘Long Tail’ (Anderson, 2006) is herewith promoted, not only as a general goal, but by detaching

as much as possible common functionality in the form of a standalone, reusable horizontal layer or as a web service.

#### 1.1 Scope

This paper considers the structure, semantic components, system representation and user presentation of ‘places’ in space, time and historical renderings in textual and other forms. It takes the view that this is an important and largely self contained topic. A notion of ‘toponym’ – ‘place name’ – is introduced. Other kinds of renderings (pictorial puns, phonetics) are mentioned for completeness only. These are more difficult or very particular to tackle at this stage.

#### 1.2 Outline of work

In Section 2 we define toponyms as understood in this work and give a particularly appealing application domain. Ottoman cancellations entail many (but not all) of the characteristics of our definition and have been worked out in a complete, demonstrable application.

We have reversed the traditional order of exposition, which first explains the inner workings of a system and then its presentation to the user. We want thus to emphasize usage aspects and especially an effort to attract the relatively uninitiated user (in technical and / or cultural terms) by offering satisfaction and joy in using such applications. Section 3 discusses the presentation to the user and Section 4 the internal representation of toponyms. The exposition is centred on Ottoman cancellations but numismatics is frequently examined as a ‘next of kin’.

2. TOPONYMS

2.1 Toponym Definition

We associate each particular toponym with time, space and its renderings either in written or in phonetic terms. A toponym is placed within a three dimensional region defined by a time interval, a ‘neighbourhood’ of equivalent written / phonetic renderings and a geographical coordinate, see T, L and S axes on Fig. 1. Either one of the three can be sharply or loosely known. There are tens of ‘Alexandrias’ in at least four continents, which from our viewpoint are all distinct. The most famous one is اسکندریه (Iskanderiya), having the same projection on the S axis as Αλεξάνδρεια and Alexandria, while the intervals of the three partly overlap on the T axis. This deals with Alexandria in Egypt. To us Alexandria in Africa (Egypt) and Alexandria in Virginia (US) are toponyms distinct to each other.

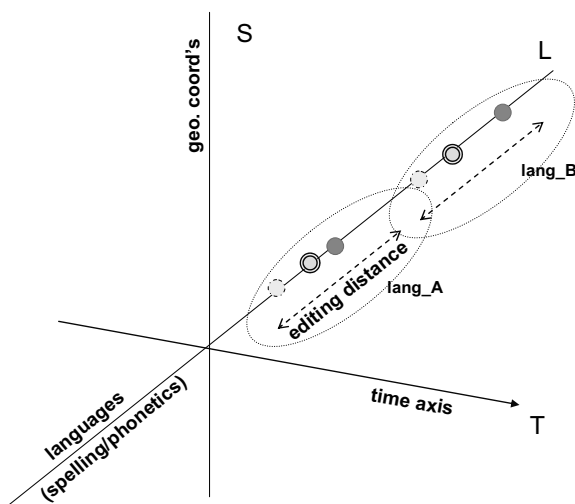


Figure 1: Toponym in time, space & language

We restrict attention exclusively to written renderings on the L axis and do no further considering phonetic renderings in this framework. Listing all L coordinates encountered at a fixed S coordinate ordered by the T coordinate gives names given to the same place by its successive occupiers, inhabitants, etc. Listing all S coordinates encountered at a fixed L coordinate ordered by the T coordinate gives migration of inhabitants or significant cultural / trade influence of the toponym having the smallest T coordinate. Hence T= [700 B.C - today], L = Αθῆναι, S = (Greece, Turkey, US, Australia ...) features a migration to the Black Sea through colonisation by Pericles at 5<sup>th</sup> century B.C. and founding of a new Athens. This has existed up to late Ottoman times rendered as اتنه (in modern Turkish script Atna, present day Pazar). In parallel, due to migrations / cultural influences we also obtain numerous modern ‘Athens’s in many continents. Notice also that the L coordinate should sometimes be taken modulo the addition of some prefix, e.g. ‘new’, turning York into New York.

2.2 A Particular Application Domain

Ottoman Cancellations are particularly interesting and provide an excellent instantiation of the ‘toponym’ concept. These cover a wide geographical area (S axis) and involve multinational, multilingual and multicultural toponyms (post

office geographical names, L axis), frequently changing over the declining period ([~1863 – 1922] on the T axis). This was also the formative period for a number of nation states in Southeastern Europe, Middle East and North Africa, which brings national and regional aspects into the fore light. Moreover their poor official documentation, resulting into ever appearing new findings and surprises, as well as rarities and forgeries add to the excitement offered by this kind of collection.

Bilingualism or rather the use of two alphabets, Ottoman / Turkish (Arabic) and French (Latin) is of prime importance. Cancellations were originally in Arabic. This is traditionally known as the ‘Brandt period’ (Brandt and Ceylan, 1963). Subsequently bilingual cancels appeared mainly in circular form. Arabic appeared mostly at the top, French at the bottom. Different Arabic calligraphic types mainly rika and later nasx, were used. Rika is a form of Arabic stenography allowing fast but at the same type aesthetically appealing handwriting. It is of Turkish origin and was widely used in the Ottoman administration (Mitchell, 1953), hence also on the cancels produced by the Ottoman Post and distributed throughout the Empire. These calligraphic trends constitute a particular additional characteristic on the L axis defining admissible regions on the TxL plane for individual S values. The Empire appears in different names: Der Saadet (‘Gate of Happiness’), Der Aliye (‘Sublime Porte’), Constantinople, Stamboul, İstanbul, all successive Ottoman designations using Farsi (Der), Arabic (Saadet, Aliye), Latin / Greek (Constantine / polis) and versions in Turkish (İstanbul, Stamboul). Additionally most of the Arabic alphabet designations appear in different periods in different calligraphic styles.

3. USER PRESENTATION

3.1 Representation, Instantiation, Punning

The internal representation of toponyms involves all three axes of Fig. 1. However few applications would address toponyms as such. More often than not, toponyms are introduced by way of artefacts, cultural objects etc. If these artefacts bear a designation of a toponym (e.g. the L axis), we obtain an instantiation of the toponym’s L axis coordinate. This can be exact, abbreviated, misspelled, malformed or in the form of a pun. Applications can address specialists, more important though those targeting the layman, hobbyist acquiring access through digital technology. In this case the rendering of the toponym on the artefact and whatever L axis coordinates of the associated toponym have to be clearly distinguished. These two do not necessarily coincide.

We draw an example from the case of postal cancellations of the Ottoman Empire.

3.2 The Ottoman Cancellation Case

Figure 2 is a screenshot of the OCIT (Ottoman Cancellations Identification Tool), already developed and demonstrable. A part of the main form is depicted.

On the right of Fig. 2 we witness a presentation of the toponyms’ L-axis. The ‘latinised’ / ‘multilingual’ radio button choice enable the user to see the rendering either in Latin or in the locally used script. This is an attempt of a coarse mapping

of the L-axis internal toponym representation; details will be discussed below.

This choice is reflected on the language / script used to offer via the combo box at lower right. These places are belonging to a particular Ottoman Empire vilayet (large administrative region) or a present day country. The figure shows Ottoman post office names in Bulgaria. However the important point is to highlight here the contra-positon to the actual instantiation of the toponym on cancellations. These are given, line by line, on the list projected on the lower part. These are exact transliterations in either 'French' (Latin) or 'Arabic' (Ottoman) or both, as found on the particular cancellation type.

The main rational of OCIT is that of identifying partly preserved or fragments of Ottoman Cancellations. Hence the instantiation of the toponym on the artefact at hand is the starting point. To this end the two textboxes on the upper left part of Fig. 2 are provided. Here the user enters whatever rendering is visible on the cancellation in 'French' (Latin) or 'Arabic' (Ottoman) or both. Wildcard characters are here in place, since part of the text is deducible from a cancellation fragment. An Ottoman keyboard integrated into the application (see Fig. 3) removes particularities in localisation and language parameterization not necessarily tractable by the layman. The user entry is automatically carried to the Ottoman text field.

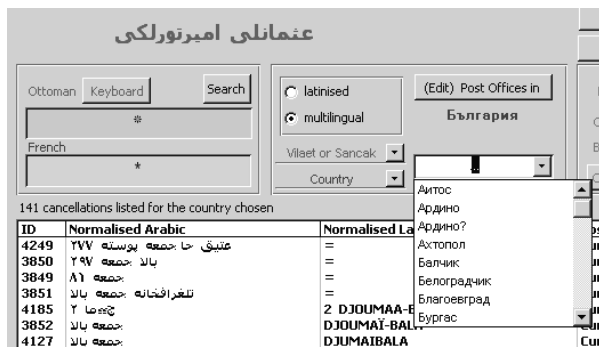


Figure 2: L-Axis Presentation and Instantiation

An example is drawn to explain the use of this keyboard. If the bottom part of a cancellation is missing, only the Arabic script is available, sometimes also partially and / or badly readable. If the left (right) part is missing, the start (end) of the French together with the end (start) of the Arabic rendering of the post office name is readable. Often these two names are different, e.g. 'DAMAS' (Damascus) in French was officially termed as شام (Sham) in Ottoman times. Hence a surviving right edge of a cancellation would allude to a place written in Arabic with a starting 'ش' (shin) and in 'French' with an ending Latin 'S' – a difficult riddle to the uninitiated. The text based search incorporated into OCIT and linked to the Ottoman keyboard is fully capable to pin down the particular candidate cancellations in this and similar cases. The final output can be in textual (list in Fig. 2) or pictorial form accompanied by textual explanations.

Within the context of OCIT presentation on the artefact and representation of the toponym's L-axis are clearly separated.

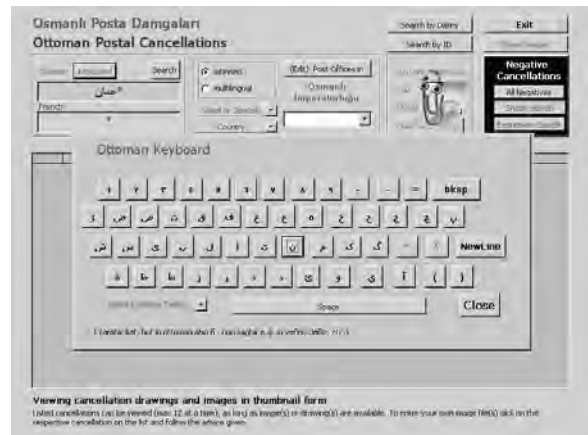


Figure 3: Integrated Ottoman Keyboard

Both are mapped, under some technical constraints, on the main user from as explained. It is then a matter of tool functionality (in OCIT and elsewhere) to successfully and effectively bridge and interrelate the two.

### 3.3 Punning

Punning is an extreme case not relevant in the case of Ottoman Cancellations. It is however important in numismatics and appears in another form in a very modern setting. It cannot be overlooked in a general discussion on the rendering of the L-axis coordinates of a toponym.

According to Wikipedia 'a pun (or paronomasia) is a phrase that deliberately exploits confusion between similar-sounding words for humorous or rhetorical effect'. Punning goes a bit further in numismatics. Selinus, a city in Magna Grecia, rather than being spelled out appears through the depiction of a wild selery plant, σέλινον in Greek. The practice is widespread. Any standard work on Greek coins (Sear, 1978) shows cases like a rose (ρόδον) for Rhodos, a table (τράπεζα) for Trapezus, a pomegranate for Side. Following the rational of OCIT a similar numismatics tool should present to the user in textual or pictorial form all such pun renderings. This would greatly facilitate the newly initiated and indeed should be an indispensable part in any such cultural tool with didactic aspirations.

Let us conclude this section on punning by a proliferating modern equivalent. Words, phrases and expressions are replaced by numerals or (capital) letters are: '2' replaces 'to', 'how are you' turns into 'how R Y'. These modern day puns are abundant in web addresses and can be considered presentation mappings of full text points on the L-axis. Hence topics discussed here can soon acquire a new and very utilitarian flavour.

## 4. INTERNAL REPRESENTATION

In OCIT post office names are of interest. The L-axis coordinate has to be represented at least four fold, see Table 1. The first ('Ottoman', i.e. in Arabic) and second ('Latinised', i.e. in 'French') columns are the ones likely to be found on the cancellation itself, more often than not altered in spelling. The second is not necessarily the modern name, even for locations in modern Turkey. Thus column 3 is essential in rendering the

post office location name, as used today, in each and every country and taking into account numerous changes due to historical, cultural and national sensitivities and a variety of other reasons. This would be the name found by an air traveller buying from the airport an internationally edited map of its destination country in the region in question. A locally edited map of the same country would print the same name in the native language and alphabet also provided by OCIT. There is however more. A loose list of further names has to be included encompassing all those names, in whatever language, as used by former 'Ottoman citizens' of various nationalities for the place in question.

Ottoman	Turkish	Latinised	Multilingual
أينه روز	Ayanoroz	Aghion Oros	Άγιον Όρος
ارضروم	Erzurum	Erzurum	Θεοδοσιούπολις
غولوس	Golos	Volos	Βόλος
يانيه	Yanya	Ioannina	Ιωάννινα
كره بنه	Gerebine	Grevena	Γρεβενά
قدس شريف	Kuds-i Şerif	Jerusalem	耶路撒冷
بيت لحم	Beyt ül-Lahm	Bethlehem	بيت لحم
اتنه	Atına	Pazar	Αθήνα, АТИА
مناستر	Manastir	Bitola	Битола, Μοναστήριον
اسكوب	Üsküb	Skopje	Скопље
دراج	Drac	Durrës	Δυρράχιο
فلبه	Filibe	Plovdiv	Πλωδिव, Φλιππούπολις
حصار صاحب	قره Sahib	Karahisar Afyon Karahisar	Ακροϊόν

Table 1: Post Office Names (L-axis Coordinates)

Thus the L-axis coordinate takes the form of a table. This is barely adequate, since even in this limited scope some of the fields would host more than one alternative values. Thus an xml representation is envisaged as a next step. This can host an open ended list of renderings tied with appropriate date intervals indicating the periods of use of each particular one. Moreover optional content, e.g. to accommodate puns, can also be foreseen.

Even for a limited historical span, Table 1 shows the complexity, albeit richness, of designating a particular geographic entity. Different cultures, different people using different languages and scripts, all pinpoint on the same coordinates on the globe. Most of the places shown have a much longer history starting long before the Ottoman Empire. Hence Table 1 is still a partial view of the L-axis covering some tens of years (end of Ottoman times) within millenniums of interest.

A horizontal layer as envisaged in this project would thus have to (i) propose a standard schema for internal representation, (ii) define an API for accessing toponyms in full accordance of the three axes presented in Fig. 1 and (iii) offer a uniform service for CRUDE (Create, Update, Delete) and querying. An application like OCIT and a similar one dealing in numismatics (ancient Greek, Roman, Byzantine, Arabic, Ottoman or modern) would then use this common service.

An array of technologies can be invoked to standardise the use and ease the development of such a horizontal service. A suitable xsd (Xml Schema Descriptor) can be invoked for (i). Different mappings to what is appropriate to present to the user can be realised via xsl (xml style sheet language) transformations (Mangano, 2005). This would also the way to package this layer as a web service thus giving a true universal access to universally applicable content.

## 5. CONCLUSION

An application covering a collection of objects with an extended geographical region in a multilingual, multinational context has brought up the problem of rendering of place names. This has been generalised and requirements have been presented to address similar issues in a horizontal way. This generalisation has led to 'toponyms', as a notion interrelating textual rendering, geographical locations and time. The internal representation and its difference / relationship with the presentation to the user have been highlighted. The actual solution demonstrable today is given by a simple data base schema. Work has been initiated to port these notions into xml and use the rich array of related technologies. The vision is a universal toponym server, with content serving a variety of applications.

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## A VERSATILE WORKFLOW FOR 3D RECONSTRUCTIONS AND MODELLING OF CULTURAL HERITAGE SITES BASED ON OPEN SOURCE SOFTWARE

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**KEY WORDS:** Cultural heritage, Promotion, Dissemination, 3D reconstruction, Virtual walkthroughs, Open Source Software, VRML, X3D

### ABSTRACT:

Nowadays commercial 3D range scanning systems have been used for the accurate digitisation of cultural heritage sites by following either terrestrial or aerial scanning approaches. Both approaches require high cost special equipment and software to cope with the vast amount of raw data. These raw data can be characterised as superfluous in cases where the main scope of the reconstruction is a web-based virtual walkthrough for tourism promotion. The low budget of a digitisation project dictates its breadth and scopes. In some cases, even leasing the equipment is prohibitive. Producing affordable 3D reconstructions for real time virtual walkthroughs is still a challenging task. The transformation of raw 3D range scanning data to an optimised textured triangulated mesh is still a non-automated process. On the basis of this description, a set of open source software applications were identified and combined on a practical workflow to be used for such 3D reconstruction projects when funding and infrastructure is at its minimum. We have attempted to evaluate the proposed process by producing a 3D approximation of a small part of the old town in the city of Kavala located in North-Eastern Greece.

### 1. INTRODUCTION

Numerous cultural 3D reconstruction projects have been crowned with success. Some of them have produced impressive results by introducing the fusion of different digitization methodologies (Alshwabkeh, 2005; Beraldin, 2005; El-hakim, 2002; Forte, 2005; Kersten, 2004; Koutsoudis, 2007; Lerma, 2005; Müller, 2004; Sabry, 2004; Sgrenzaroli, 2005; Sormann, 2004; Sundstedt, 2003; Suveg, 2000; Takase, 2003; Tsioukas, 2005; Tsirliganis, 2001; Valzano, 2005; Van Gool, 2002). The main purpose behind such a combination is no other than acquiring the best of the different approaches. In other cases this fusion aims at the improvement of the ‘*automation level*’ of the whole digitisation process. Nonetheless, it is still a highly active research area as there is still no panacea methodology to comply with the multiformity of the cultural thesaurus. Fully automated methods for transforming the raw data of a 3D range scanner to an optimised triangulated mesh for virtual walkthroughs are still under research. Modern techniques required at least some minimum user input during the initial reconstruction phase and more interactive work for further conversion of the large datasets into web-optimised mesh structures (Žára, 2004).

A key factor that determines the most applicable digitization method for a project is the substantial scope of the final 3D digital model. It is very common to be affected by the importance of the theoretical and scientific aspects of a project, but no one should disregard the primary role of funding. Projects that involve 3D reconstructions of a cultural heritage site are not an exception to this rule. For example, consider a low budget project aiming at the dissemination of a monument over the web. A low polygonal mesh with high resolution texture maps would be efficient for such an application as in fact it doesn’t aim at digital archiving, at architectural or any other type of study but only at the cultural heritage dissemination or tourism promotion. Modern range scanners provide accurate and dense measurements. Those can be

described as ‘*superfluous*’ in cases where low geometric complexity building facades are to be captured. At the same time, the project’s budget might not be able to cover the expenses of even leasing the digitisation equipment. On the other hand, there is an additional cost of the commercial software that is required to filter and align the raw data.

This work emphasizes on a low budget approach to the dissemination of cultural heritage through an influential medium such as the web, by following well established image based reconstruction methodologies based on OSS (Open Source Software), low cost off-the-self components, like consumer digital cameras, on-site empirical measurements and available topographical studies of the area.

### 2. OPEN SOURCE SOFTWARE (OSS) IN CULTURAL HERITAGE 3D RECONSTRUCTION PROJECTS

In this paragraph we discuss the role of OSS in software development, the selection criteria of an OSS application and our proposed OSS 3D Reconstruction Workflow (3D-OSSRW).

#### 2.1 Selecting Open Source Software (OSS)

Several working groups such as software engineers, computer scientists as well as economists and management scientists are attracted by the production of OSS. It is interesting for someone to understand this apparently unique mode of source code production (Gläser, 2003). More than ten years have passed since the OSS movement came out. Nowadays, numerous OSS applications present tremendous gains in quality, efficiency and cost saving. Functionality, reliability as well as performance can be considered as principal criteria when selecting such software. *Open Source Maturity Model* (OSMM), *Business Readiness Rating* (BRR) and *Method for Qualification and Selection of Open Source Software* (QSOS) are evaluation

frameworks that have been arisen in order to compare and assess OSS.

In our case though, the software selection was biased by the limited number of OSS that are capable to perform the specialised functions required in a 3D reconstruction project. Nevertheless, the identified applications have good reputation for performance and they provide some functionality that can also be found in commercial software. Thus, they form a stable while versatile software arsenal which is applicable in low budget 3D reconstruction projects. The following software components compile the proposed toolset:

- a) *Panorama Tools* is a collection of software programs used for creating panoramas from multiple images. The core software was originally written by Prof. Helmut Dersch of the Fachhochschule Furtwangen. The software includes *ptpicker* and *ptstereo* software components to create sparse 3D meshes based on the shape from stereo technique from pairs or many images (Dersch, 2003).
- b) *Hugin* is a cross-platform open source panorama photo stitching program developed by Pablo d'Angelo. It is a frontend GUI for the Panorama Tools.
- c) The *GNU Image Manipulation Program* (The Gimp) is a raster graphics editor for creating and processing bitmap graphics. It also provides partial support for vector graphics. The project was initiated in 1995 by Spencer Kimball and Peter Mattis and is now maintained by a group of volunteers; it is licensed under the GNU General Public License.
- d) *Blender* is the open source software for 3D modelling, animation, rendering, post-production, interactive creation and playback. Available for all major operating systems under the GNU general public license.
- e) *Voodoo Camera Tracker* is a camera tracking tool for the integration of virtual and real scenes. It can provide a coarse 3D point cloud based on feature points that are automatically detected and extracted from a video sequence. This non-commercial software tool is developed for research purpose at the Laboratorium fuer Informationstechnologie, University of Hannover.
- f) *VeCAD-Photogrammetry* is a simple tool for architectural photogrammetry that performs basic processes such as photogrammetric image rectification using vanishing points and photogrammetric rectification based on measured control points (Tsioukas, 2007).
- g) *Meshlab* is an open source, portable, and extensible system for the processing and editing of unstructured 3D triangular meshes and point clouds (Cignoni, 2008). It provides a set of tools for editing, cleaning, healing, inspecting, rendering and data format converting.
- h) *VCG ShadeVis* computes a simple, static per-vertex ambient term. This effect, commonly known as ambient occlusion, is aimed at providing more faithful shading for realtime rendering (Cignoni, 2008b).

*VeCAD-Photogrammetry*, *Hugin* and *Panorama Tools* compose the *Image Rectification Toolkit* (IRT) while *Blender*, *Meshlab*, *VCG ShadeVis* and *Voodoo Camera Tracker* compose the *Geometry Modelling Toolkit* (GMT).

## 2.2 The Open Source Software 3D Reconstruction Workflow (3D-OSSRW)

The 3D reconstructions that are produced by 3D-OSSRW are mainly considered for promotional purposes and not for digital

archiving or scientific study. They are applicable for realistic real time walkthroughs over the web. Figure 1 depicts the two main phases of the proposed workflow. These are:

- The *Data Acquisition Phase* (DAP) that denotes the actual fieldwork.
- The *Reconstruction Phase* (REP) which is performed with the use of the proposed OSS arsenal (IRT and GMT).

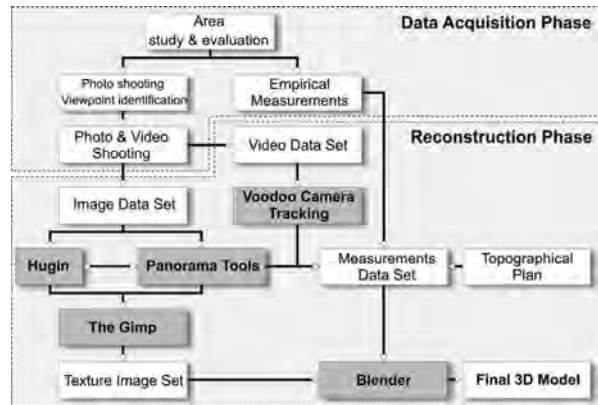


Figure 1: The two phases of the proposed 3D-OSSRW

### 2.2.1 The Data Acquisition Phase (DAP)

DAP comprises of empirical procedures that do not require the use of any of the proposed software applications. More specifically, during this phase a thorough study of the target site is performed in order to decide on which of the geometric features of the buildings and surroundings are going to be modelled. It is a significant phase as the empiric method that is going to be followed for measurements and photo shooting will be driven by the decisions made at this point. This decision phase could be described as a 'mental polygonal modelling of the site' performed by the development team. Experience on 3D computer graphics modelling is considered as a subjective criterion on wisely identifying those parts of the real world that are going to be modelled. Thus, DAP is partially dependent on the developer's experience.

It is a fact that our brain has two major paths for processing visual information, the 'where path' that determines object locations and the 'what path' for identifying objects (Cho, 2003). The previous statement is highly correlated to real time virtual reality applications such as 3D walkthroughs. The evaluation of the area by identifying characteristic features of the objects is an important factor that affects realism (the 'what path') of the final 3D model. It is important for a development team to have in mind that the introduction of real time 3D graphics techniques derived from the multimillion computer game industry is always an advantage in the visualisation of 3D reconstructions. Fundamental techniques such as billboards, tiled textured maps, vertex paint shadowing, ambient occlusion and ray trace *shadow baking* techniques in combination with double texture maps can be applied using the proposed OSS for a realistic result.

Once the decision phase is completed, photoshooting is then performed. But before that a set of viewpoints also need to be identified. The selection of appropriate viewpoints aims at the

minimisation of the geometric declinations for images that are going to be used for texture mapping. For example better results are derived for capturing building façades when the camera optical axis is positioned as much perpendicular as possible to the façades. On the other hand, the image sets that are going to be used with the *ptpicker* software for 3D reconstruction during the REP phase should be taken bearing in mind the limitations of the *triangulation principle* as the accuracy depends on the distance of the feature which is relative to the stereo base. In general, distances much larger than the stereo base (eg > 20 times) or features much smaller than the stereo base are not resolved correctly. A topographical design of the area might give an advantage on identifying those viewpoints and it can also provide a well structured document that can be used during the *on site* presence for keeping notes related to viewpoints. The photographic dataset should cover the maximum possible information that is visible to the visitor of the real site. Furthermore, a set of video sequences might be proved also helpful, as it could be used during REP for the production of sparse 3D point clouds with the use of a camera tracking software (e.g. Voodoo Camera Tracker).

The final task of DAP is to manually measure distances between characteristic points of objects within the scene, which is usually referenced as an empiric method. The definition of the coordinates is being done on an arbitrary coordinate system on planar surfaces of the scene. The method is simple and productive, portable and of low cost. On the other hand it is of low accuracy and demanding in terms of time of physical presence on-site. Nevertheless, it can be successfully applied when buildings have simple shapes, or there is a need for recording a sectional plan or sections of interiors (Fritsch, 1999). A good practice might be that the initial recording of the measurements could be done on topographical designs or rough drawings or even on printouts of photographs that were previously acquired. Despite the low density of the measurements and the simplistic scientific aspect, the low cost of the equipment required in combination with the readily available measurements prove to be adequate in situations where high accuracy and dense data are not required.

### 2.2.2 The Reconstruction Phase (REP)

After the completion of the DAP phase, the REP phase is initiated and it involves the processing of the collected data by using the proposed software collection.

*Panorama Tools* can provide a low density triangulated mesh based on the *shape from stereo* technique by using the *ptpicker* and *ptstereo* software components. The output mesh doesn't reflect real dimensions but only proportional distances. This is where the empiric method measurements become practical to transform those proportional distances to real-world dimensions. Alternatively, *Voodoo Camera Tracker* can provide another approximation of parts of the scene in the form of a point cloud. Both data sets can be imported into *Meshlab* for alignment and further processing. Then with the use of *Blender* an optimised polygonal wireframe can be built manually by combining also the empiric measurements and the topographical plans. A very useful approach towards more efficient 3D modelling is to use the topographical plans as backgrounds within the modelling application. This operation can be achieved in *Blender* as it allows the developer to lock the background in respect with the 3D mesh position so that during modelling, camera zooming functions are applied to both background image and 3D geometry.

The modelling phase is, in general, a time consuming process and unavoidable even in situations where different measuring approaches are followed (e.g. 3D range scanners). Assuming that the budget was not an issue and a range scanner was available for the project, the development team would still need to:

- Perform manual polygonal mesh processing in order to generate a web efficient low polygon mesh from the initial dense point cloud.
- Follow mesh simplification and hole filling procedures on the dense polygonal mesh that was automatically derived from the range scanner's data processing software.

According to Žára (Žára, 2004), due to the lack of directly applicable reconstruction techniques, manual 3D modelling from scratch always plays an important role. Additionally, another challenging part during the DAP phase is the modelling of free-form objects usually found in nature. Foliage in general cannot be captured even with high accuracy range scanners due to occlusions and 3D modelling is necessary when realism is required. In general, different approaches can be followed during the modelling phase, i.e. tree representations using billboards, empiric 3D modelling or even freeware 3D models.

The texture mapping of the polygonal triangulated mesh is also proposed to be performed manually within *Blender*. In comparison with the proposed approach, using colour information from 3D scanner range data (e.g. colour 3D point cloud) would allow a faster generation of orthographic photos from the buildings façades. Nevertheless, the texture maps are created based on the image dataset. The IRT is used for image rectifications and stitching. These software tools provide the developer with image processing procedures for warping a digital image on the basis of geometric principles so that perspective is controlled and an orthogonal image is produced (Debevec, 1996; Farinella, 2006; Lingua, 2003; Pollefeys, 2001; Rushmeier, 2000). On the other hand, *The Gimp* can be used as a typical image processing tool, to combine multiple texture maps, to enhance images, to correct colours, brightness and contrast or to create tile maps. The texture mapping of the mesh is performed using the rectified image dataset. *Hugin* and *Panorama Tools* can also generate image panoramas that can be mapped on planar surfaces or hemispheres that could be used as backgrounds in areas where modelling is not applicable.

## 3. APPLYING THE 3D-OSSRW

In this chapter, we discuss a case study where we have applied the 3D-OSSRW. We discuss an initial project planning and the issues arised during the DAP and REP phases.

### 3.1 The old city of Kavala

We have selected an area with cultural heritage significance that is located in the city of Kavala (North-Eastern Greece). It is a picturesque area with cobbled roads that lead to an appealing example of Turkish house architecture of the 18th century (where Mehmet Ali Paşa, founder of the last Egyptian royal line, was born) and a Christian Orthodox church dedicated to Virgin Mary. Both are located within the remnants of a Byzantine castle. The house was built in 1720 and it is preserved today in a very good condition. The residence occupies a prime position so that the owners could experience a panoramic view from all sides. The main entrance faces the

harbour of Kavala while the other side has a view to a beautiful bay. The house that was renovated before the Second World War was used as a museum until recently and it was one of the biggest (330 m<sup>2</sup>) mansions in the city.

### 3.2 Planning the reconstruction project

With an initial project planning we allocated a total time of 500 person-hours over a two month period for the whole reconstruction project. This initial estimation turned out to be accurate enough as the completion of the project was achieved within these deadlines by only two individuals. It should be noted though that the project duration is related to the complexity of the reconstructed area. Based on the experience gained through this project, and the time needed for each task we came up with the time allocation chart shown in Figure 3. In future works, we will try to improve this type of chart by introducing data from similar projects in order to provide a truthful rough guideline for other projects. Furthermore, the total duration of each task appears in table I. Most of the development time was allocated to mesh modelling and texture mapping. Automation of these processes, in cases where there is a need for optimised geometry, is still challenging and hard to be achieved. Although the workflow provides a simple, yet low cost approach to 3D reconstruction is governed by low mesh complexity, high demands in terms of time of physical presence on-site and basic 3D modelling experience.

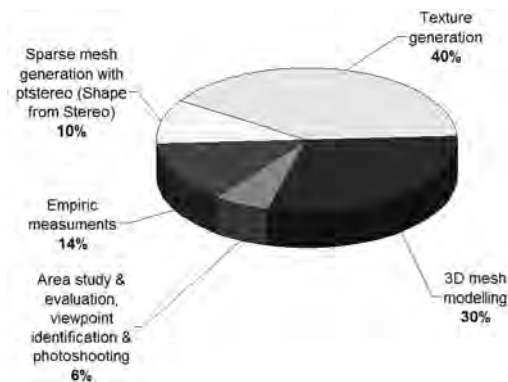


Figure 2: Percentages of total time (500 person-hours) allocated per task for this project

Task	Person hours
Area study & evaluation, viewpoint identification & photoshooting	30
Empiric measurements	70
Sparse mesh generation with <i>ptstereo</i>	50
Texture generation	200
3D Mesh Modelling	150

Table 1. Total person hours per task as allocated for this project

For decades now texture maps provide the illusion of details in computer graphics (Rushmeier, 2000). Experiments have shown that pictorial realism plays an important role in an immersive VR system. Such an experiment involved the expression of texture map data as a relative weight contributing to the overall realism metric of a VR system. This weight was usually much higher than the weight of geometric data (Cho, 2003). This is another testimony of the importance of texture mapping when

accessing VR systems over the Internet, where the volume of transferred data is still a crucial issue.

### 3.3 Generating the 3D model

During photoshooting, one can almost instantly understand the difficulties that arise (viewpoint selection limitations and occlusions) as the low budget approach does not allow the use of any special lenses (e.g. wide angle, fisheye lenses) or temporary scaffolding. A total of 900 photos were taken using an 8 Mpixels *prosumer* digital camera along with a total of 250 measurements based on empiric methods. The characteristics of the camera can be found in Table 2.

Sensor Size	2/3" – (8.80 x 6.60 mm)
Sensor Type	CCD
Focal length	6.1 mm
Horizontal field of view	72°

Table 2. Digital camera characteristics

An average of 30 pictures per building were used for both geometry and texture maps creation. Moreover, obstacles appearing on images were manually removed or hidden through image registration or, in worst cases, through manually performed ‘*image inpainting*’. Before removing the obstacles, the images were processed with the IRT to perform radiometric and perspective corrections of the façades. The final texture maps were produced in most cases by stitching multiple images.

The topology of the area played a key role on identifying appropriate viewpoints. Monitoring weather conditions during photoshooting is crucial in order to avoid heavy shadow casting and severe contrasts. As mentioned before, texture information is the basis of realism in such 3D reconstructions. Thus, it was essential to collect the image data sets under similar lighting conditions (e.g. overcast weather). That way it was possible to provide realistic lighting by using only texture maps. In some cases, though, natural hard shadows were impossible not to be captured. Nonetheless, one could argue that natural shadows appearing on texture maps could significantly improve realism as they capture real world actual appearance. Furthermore, visual quality could be improved by using artificial shadowing techniques such as ray trace and ambient occlusion baked on texture maps or by following the common but less visually effective vertex painting approach.

The user interface of *Blender* proved to be exceedingly efficient for such applications by providing the *One Hand On Mouse, One Hand On Keyboard* (OHOM-OHOK) approach. Figure 3 shows the sparse wireframe (red coloured) that has been imported from *ptstereo* into *Blender* and visualised on the top of a topographical map. The additional geometry that is presented in the same figure has been produced by using the empiric measurements. Trees and bushes were depicted either using billboards or cross planes and in some cases empiric 3D modelling. In order to estimate their height an attempt was made to measure a single point on the top of each tree using *ptstereo*. Once the model’s geometry was completed, the use of *shadevis* allowed the per-vertex shadowing of the mesh using the ambient occlusion technique. Then the texture mapping procedure was completed using the rectified textured maps. The final 3D reconstruction covers only those parts of the area that are visible to the real visitor and thus it is not a complete reconstruction.



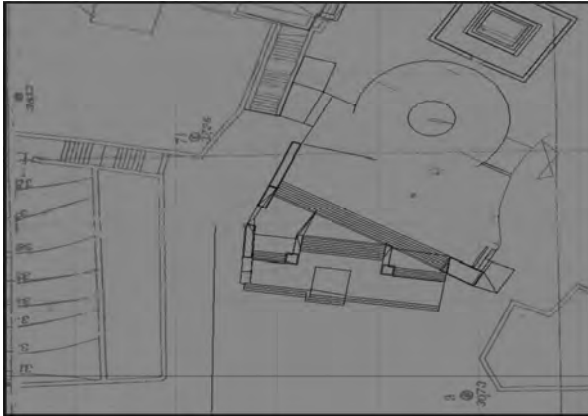


Figure 3: The 3D modelling is performed within Blender based on topographical maps, empiric measurements and sparse triangulated mesh derived from *ptstereo*

### 3.4 Publishing the 3D reconstruction on the Web

The final model of the reconstructed area (Figure 4) was exported to the ageing VRML, which is now being slowly replaced by X3D. The final model is composed by a total of 11,673 vertices that define a set of 17,832 facets. Such geometric complexity can easily be handled even by low-end graphics cards. The data transfer bottleneck actually resides on the memory size of the graphics card, as the texture data are memory demanding.



Figure 4: Screenshots during a virtual tour inside the reconstructed area

Multiple versions based on different texture qualities can easily serve different bandwidth connections (Table 5). Texture information comprises almost the 90% of the total amount of data. A solution to the texture data transfer problem was given by resizing the texture maps (*JPG and PNG images*) resulting in reduced visual quality whereas maintaining acceptable download times in order to satisfy a larger target group of Internet users. Multiple quality levels of 3D models and geometry compression are active research areas. Unfortunately, the VRML source code is interpreted only after the completion

of its transfer to the client. Thus, there is no form of true progressive transfer of the 3D model apart from the ability to manually split the geometry into multiple files. This ‘*Level of Detail*’ approach which is supported by the VRML standard it is not applicable in this case due to the low polygonal mesh data that would be increased if split into multiple files due the textual syntax overhead that would be introduced. Additionally, in most cases the source code is transferred by using the lossless compressed data format GNU zip which reduces drastically the downloading times.

In order to provide some objective metrics to the different versions of the reconstruction, we measured the PSNR on three images (one from each of three quality version we produced) covering the same viewpoint of the reconstruction. Considering the *high quality* version as reference image, a PSNR value of 38.9 dB was derived when comparing with the *medium quality* and a value of 31.4 dB when comparing with the *low quality*.

Transfer Speed	Mesh Data	Texture Data Quality		
		Low	Medium	High
9.6 Kbps	03:10	1:00:10	1:48:20	8:33:29
14.4 Kbps	02:07	40:06	1:12:13	5:42:19
28.8 Kbps	01:03	20:03	36:07	2:51:10
33.6 Kbps	00:54	17:11	30:57	2:26:43
56 Kbps	00:32	10:19	18:34	1:28:02
64 Kbps	00:28	09:02	16:15	1:17:01
128 Kbps	00:14	04:31	08:07	38:30
256 Kbps	00:07	02:15	04:03	19:15
512 Kbps	00:03	01:08	02:02	09:38
1 Mbps	00:01	00:34	01:01	04:49

Table 5: Download times (hh:mm:ss) for the three different texture quality versions of the same 3D scene over networks with different bandwidths. In grey shaded cells appear the acceptable downloading times

Regarding the quality of the resulted 3D model itself, geometry accuracy errors are not constant throughout the 3D model due to the empiric method used. Thus, it is not possible to estimate a uniformly distributed accuracy error factor. This would be possible only in cases where a 3D range scanner would have been used and under certain constraints such as the distance of the scanner from an object. Nevertheless, this variable accuracy error has seamless visual impact when considering the initial purpose of the low-polygon reconstruction which is the promotion of heritage through web by using virtual walkthroughs. Furthermore, many features such as windows or doors are visually depicted through texture maps and are not 3D modelled. It should also be noted that, all empiric measurements are accurately reflected in the final 3D reconstruction when measuring distances between vertices.

In general, the versatility of the 3D-OSSRW allows higher levels of geometry detail to be achieved. However, when considering the additional modelling time as well as the additional extra time required for measurements, then the cost efficiency of the workflow becomes remarkably low and reaches levels that its applicability is questionable. Nonetheless, it has already been proven that there is a limit on creating compelling VR content by only working on improving geometric details (Cho, 2003).

#### 4. CONCLUSIONS

Cultural heritage is primarily promoted over the Internet by digital photographs and textual information, but now it is slowly complemented by virtual walkthroughs based on 3D reconstructions. A 3D model can be virtually explored, providing better perception than a typical photograph. The use of colour point clouds derived from range scanners as the visualisation approach is highly applicable when streaming data over the web but the visual result is adequate only for visualisation of artefacts or monuments from a distant point of view and not for virtual walkthroughs. The use of textured map triangulated meshes has been proven by the game industry, through first person 3D computer games, as more applicable. Furthermore, today's hardware limitations (e.g. graphics cards, processing power, network bandwidth, etc) render the visual realism of an *over-the-net* 3D reconstruction inferior to a photograph in terms of visual details.

In this work, we proposed 3D-OSSRW, an OSS based workflow for the 3D reconstruction of cultural heritage sites. The 3D-OSSRW does not require any programming skills as a prerequisite. Therefore, even a computer graphics enthusiast experienced with 3D graphics can follow the proposed workflow to produce realistic 3D representations of existing urban areas or sites without the presence of any expensive software or hardware. The fidelity of the final 3D model is by far inferior to any other 3D model that could have been created by geodetic measuring equipment such as terrestrial 3D laser range scanners or theodolites. Better results have already proven to be obtainable by combining different techniques only when the cost of leasing or buying the required equipment is within the budget (Beraldin, 2005; El-Hakim, 2002; Sgrenzaroli, 2005; Takase, 2003; Valzano, 2005).

Recent developments of prototype/beta X3D clients could improve the efficiency of the source code that describes the 3D model of the reconstruction as will allow real-time streaming of 3D virtual worlds. VRML lacks many features and requires a lot from the hardware and network connection, a more efficient X3D version could be exported from Blender in order to support new features. In the case of texture information, the ratio between quality and compression can be improved by applying the newly developed JPEG2000 compression scheme that is supported by some X3D clients and results better visual quality, usage of regions of interest and more. Novel VRML/X3D viewers such as the *BS Contact VRML/X3D* provide extensions beyond the VRML standard that allow modern real-time graphics technologies to be used such as double texturing for baked ray trace shadows as well as real-time stencil shadows.

Additional, topographical and historical information could also be collected and attached with the architectural elements of the area. This information is available to the virtual tour visitor by means of tags that VRML/X3D browsers allow to appear when the mouse cursor passes over the buildings. Concluding, the 3D model could be accompanied by an informative website composing a complete on-line tourist brochure.

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## PROCESSING CULTURAL HERITAGE IN LIGURIA: A CASE STUDY IN GOOD PRACTICE

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### ABSTRACT:

The paper describes as a case study a model of an innovative, integrated web system providing access to different types of source materials, digital resources and data, obtained through the digital processing of pre-existing resources according to common standards. From 2006 the Regional Directorate for Cultural Heritage and Landscape in Liguria has developed its digital services following the MINERVA project standards and guidelines and has worked on surveying and cataloguing, with the MICHAEL project, the digital collections belonging to the Institutions located in the Regional area, and preparing contents to be contributed to CulturalItalia, the Italian culture portal. At the same time, the Directorate has actively cooperated with the Region Liguria in georeferencing local cultural heritage sites and digitalising the related archival documentation. The synergy between the above mentioned activities led to the design of a set of georeferenced cultural routes, which are specific to the Ligurian territory. In fact, MICHAEL census allowed to identify and interconnect by topic the relevant digital resources, which had been made available through the Web thanks to the creation of quality cultural websites funded by CulturalItalia, according to MINERVA *Cultural websites quality principles* and *Technical guidelines for digital cultural content creation programmes*. The cultural routes, currently under construction, are the result of a synergy between the activities mentioned above. They will be made accessible on a specific section of the Directorate website, which is being developed with the use of the kit for quality website production, Museo & Web, provided by MINERVA. The cultural routes will be also made available through CulturalItalia and will thus provide the public with a well-organised quality information from many different sources.

### 1. INTRODUCTION

This paper presents a case study of the uses of good practice within the framework of MINERVA standards and guidelines and the activities that over time derived from its results.

The case study concerns the implementation of standards, guidelines (MINERVA 2004; MINERVA 2006) and principles for quality web applications (MINERVA 2005a; MINERVA 2005b) defined and agreed over the past five years by project MINERVA (Ministerial Network for the digital promotion of cultural heritage, <http://www.minervaeurope.org>), a series of extended MINERVA sub-projects (including MINERVAplus and MINERVAeC), the international project MICHAEL (the Multilingual Inventory of Cultural Heritage in Europe, a spin-off of MINERVA, the Italian national project CulturalItalia (<http://www.culturalitalia.it>), and the digital services of a network of cultural institutions located in Liguria.

Liguria is a region placed in the North-West of Italy, facing the Ligurian Sea. Although rich in natural beauty and cultural heritage, Liguria is still an out-of-the-way location, distant from the main touristic routes. The main town, Genoa, is used as a stopping point for cruises across the Mediterranean Sea but the surrounding province remains otherwise not well known to tourists.

New technologies and digital media channels represent a new medium for the cultural promotion and tourism development in the region.

The paper will go through the different conceptual and chronological stages of the process that has been developed and is still in progress.

### 2. FIRST STAGE: THE PUBLICATION OF NEW QUALITY CULTURAL WEBSITES

This process started in 2006, when the Regional Directorate for Cultural Heritage and Landscape in Liguria – Direzione Regionale per i Beni Culturali e Paesaggistici della Liguria, a regional administration coordinating all local bodies under the Ministry for Cultural Heritage and Activities (MiBAC) – began to collaborate with the CulturalItalia project (a national web portal dedicated to Italian Culture) involving the generation of quality new websites and the updating existing websites (according to the MINERVA guidelines) of participating cultural institutions.

As a result of subsequent work, carried out under the coordination of the Regional Directorate and in continuous cooperation with the central Ministry for Cultural Heritage and the MINERVA staff, the following Ligurian based websites were either created or enriched:

- the official website of the Directorate (Direzione Regionale per i Beni Culturali e Paesaggistici della Liguria): <http://www.liguria.beniculturali.it>
- the website of the Archaeological Service of Liguria (Soprintendenza per i Beni Archeologici della Liguria): <http://www.archeoge.liguria.beniculturali.it>
- the website of the Architectural and Landscape Heritage Service of Liguria (Soprintendenza per i Beni Architettonici e Paesaggistici della Liguria): <http://www.sbapge.liguria.beniculturali.it>
- the website of the Historical and Artistic Heritage Service of Liguria (Soprintendenza per i Beni Storici, Artistici ed Etnoantropologici della Liguria): <http://www.soprintendenza.liguria.beniculturali.it>
- the website of the University of Genoa Library (Biblioteca Universitaria di Genova): <http://www.bibliotecauniversitaria.ge.it>
- The web portal, Culture of the Region of Liguria: <http://www.CulturainLiguria.it>.

The publication of the above mentioned websites, completed in January 2007, marked the growth of a new perception of the cultural web in Liguria and of a new awareness, for the Public Administration, of the potential of uses of Web communication (Calandra 2007).

From this moment on, in fact, public websites began to be used as the foundation of a totally new strategy for the dissemination of cultural content and cultural information, i.e. one that uses the Web as a stepping stone and a launching pad rather than as just a landing place for such information.

It was, moreover, also observed that public web services are enhanced not only by the interconnection of individual sites but also by the use of more comprehensive, larger-scale, portals within the context of a pre-defined public communication strategy. The synergy brings an overall improvement of service quality and a substantial growth of knowledge and cultural interest among the users of the public services.

### 2.1 Liguria Vincoli

This awareness was increased once the website Liguria Vincoli was published online (<http://www.liguriavincoli.it>). This website publicly presents to the citizens the map of all of the cultural sites that were “legally bound” in the territory of the Liguria Region, according to the Italian Law on Cultural Heritage and Landscape (Di Dio, 2007; Voci, 2008; Gaggero, Calandra, in press; Calandra, in the APPENDIX B).

Italian law, in fact, provides for items of cultural heritage or for sites under the responsibility of a private owner to be pronounced as publicly relevant and of national interest; this provision provides for private sites to be safeguarded and preserved in accordance with the same guidelines covering public sites (D.Lgs. 42/04).

The website is under the responsibility of the Liguria Regional Directorate for Cultural Heritage and Landscape, in cooperation with the local government of the Region of Liguria.

It currently registers and gives integrated access on a geographical basis to about 6000 sites that were legally protected because they were considered to be of public interest as cultural landscapes, archaeological sites, or items of architectural heritage.

For the first time in Liguria, archival, photographic, cartographic and alphanumeric data held under the responsibility of two different local “Soprintendenze” (the Architectural and Landscape Heritage Service and the Archaeological service) were unified via a single point of digital access; they were made accessible to the public in an integrated way, based on a common georeferencing platform, derived from one that had already been adopted by the Region of Liguria.

This is the result of a systematic programme for the digitisation of all archival documents kept under the responsibility of the Architectural and Landscape Heritage Service and the Archaeological service, and the Region of Liguria, the latter responsible for Landscape heritage, carried out by the appropriate institutions according to the technical and quality standards of MINERVA and under the coordination of the Regional Directorate.

The digitised resources obtained were then organised and made available to the public, based on the consideration of the importance of the integration between physical and digital resources and information content.

The integration of the data enables their interconnection and allows new interpretations, producing a more complete and quality enhanced information framework, leading to the generation of new thematic paths. It makes it possible, for instance, to cross-search the system on a geographic basis finding thorough information for each location concerning architectural and archaeological knowledge and automatically calculating areas, distances and density of settlements.

Liguria Vincoli might be defined as a tool for further discovery of the territory, based on high-profile public service enhanced by a high quality communication strategy on the Web.

### 3. THE CENSUS OF THE DIGITAL RESOURCES AND THE CREATION OF NEW THEMATIC ROUTES

The second stage of the process started during the first half of 2007, with the start up of the process that led to the survey and the cataloguing of digital collections belonging to cultural institutions located in the territory of the Region Liguria, in the framework of the international project MICHAEL (Bartolini, Calandra, 2008).

MICHAEL (Multilingual Inventory of Cultural Heritage in Europe) is a project funded by the eTEN programme of the European Commission (2004-2008) in which 19 European countries currently take part and which is coordinated by the Italian Ministry for Cultural Heritage and Activities.

MICHAEL has launched a European portal (available at the url <http://www.michael-culture.org>) making European digital cultural heritage accessible on a multilingual basis and promoting it to a worldwide audience. It is based on a network of national cataloguing databases, containing national digital cultural collections, which contribute their data to the European portal through an automatic harvesting procedure. The Italian portal is available at the url <http://www.michael-culture.it>.

The Ligurian digital cultural resources described so far number about 250, two hundreds of which are already available in the national portal. The cataloguing started in May 2007 and it was originally foreseen that it would last for one year; however, the Region Liguria has already funded a continuation up until the

end of 2008. The final objective to be completed is for the maintenance and updating of the cataloguing to become a part of the ordinary work of Ligurian cultural institutions.

The cataloguing of the Ligurian digital collections is under the responsibility of the Regional Directorate for Cultural Heritage and Landscape. The cultural collections selected for the first phase of the census were those which, more than others, represented the specific characteristics of the Ligurian territory. They were identified in cooperation with the Region Liguria, in order to guarantee that the census covered all relevant cultural resources.

Among the digital resources identified through the MICHAEL census, some websites were selected as the Ligurian contribution for the detailed indexing by the Italian cultural portal CulturalItalia, which includes a section devoted to a catalogue of online Italian cultural resources.

Among the Ligurian websites is to be found Damasco velluto jeans: centro studi tessuto moda, a website devoted to the history of textile production in Genoa (<http://www.dvjgenova.it/>).

### 3.1 Cultural routes in [www.liguria.beniculturali.it](http://www.liguria.beniculturali.it)

A new ring was recently added to this chain, linking back to the above mentioned website of the Regional Directorate.

A new project, aimed at the development of a section (“Percorsi tematici”) was begun within the Regional Directorate website. The English translation sounds like “thematic routes”, in the meaning of themes that coincide with a component, physical or not, of the territory.

The thematic routes will virtually reassemble a map of the cultural evidence in the territory, based on both bibliographic sources and on-site research.

The first set of cultural routes, to be published online soon, includes the following:

1. Rural built heritage in Liguria;
2. The appearance of the first men in Liguria and its positivistic interpretation;
3. Polychromy and use of colour in Liguria;
4. Superba antiqua: The taste for antiquities in Genoa.

The choice of such specialist subjects is in line with a new vision for cultural websites, not conceived of as simple containers and distributors of all kinds of information, but as qualified and trustworthy access points to selected contents made available to specific search strategies.

Although specific to the Ligurian territory, these digital routes are unique and valuable for a wide audience at the national and international level.

They are, first of all, thematic paths. They can, however, be converted into physical routes to be covered across the territory, stopping in real locations and places.

An interactive ‘physical’ route including stopping places such as the Genoa State Museums, the Royal Palace Museum and the National Gallery in Palazzo Spinola is currently under development. It will be made available, as will the other digital cultural routes, within the website [www.liguria.beniculturali.it](http://www.liguria.beniculturali.it),

and will be interconnecting the websites and web services offered by the institutions included in the route (among them: <http://www.palazzorealegenova.it>; <http://www.palazzospinola.it>).

### 3.2 Technical choices

The website, in which the thematic routes are going to be integrated, has been developed, from the early beginning, through the tool Museo & Web, a kit promoted by MINERVA project for the creation of quality cultural websites.

Museo & Web is available in Italian, English and French, on the Minerva website at <http://www.minervaeurope.org/structure/workinggroups/userneeds/prototipo/index.html>.

The kit provides also a Content Management System, freely available to all cultural institutions wishing to make use of it (<http://www.minervaeurope.org/structure/workinggroups/userneeds/prototipo/cms.html>)

With the CMS “Museo & Web”, which manages also multilingualism, it is possible to create, modify, and control both individual pages and whole logical sections of one’s web documentation, establishing rules, roles and levels of access according to one’s own specific requirements.

The system permits even non expert personnel to actively participate into the process of creation and publication of the contents, bringing one’s own contribution in real time, according to one’s skills and competence.

This CMS can be used freely by museums and other cultural public and private institutions, adapting it to one’s own need. It is principally characterised by three features:

- 1) The classic function of building HTML pages, making it possible to maintain hierarchical structures between pages
- 2) A media archive, storing images and multimedia files
- 3) Modules customised for cultural contents (among which, short cataloguing cards, itineraries, thematic routes, glossary, etc.).

As regards thematic routes, cultural content can be organised and searched at different levels, and the content can be associated to cataloguing cards, itineraries and stopping places. Of course, digital resources present in the media archive may be linked from the thematic routes.

### 3.3 Criticisms

The first problem was to find a way to combine materials which are very different in terms of origin (both digital and physical, then to be translated into digital form) and destination (pre-existing web-sites; the construction of new maps and plans of Genoa).

The second was to organize, in a hierarchical manner, general and specific texts, catalogue forms and images, according to the tree-structure characteristic of computer languages: the most impressive work was to arrange the works of every author (a large number) designating texts as priority or secondary, with a presentational logic which is very different from that used for “printed” materials.

At the end, another problem was the copyright for images published in other websites: the solution was to link directly to

the sites, with the immediate consequence of the “advertising” for the site quoted.

#### 4. CONCLUSION

One year after the publication of some of the main cultural and institutional websites, with the cataloguing of further digital cultural collections continuing, we see that the quality and quantity of the cultural information made publicly available has changed the way Ligurian cultural heritage is being approached by the public.

Users, in fact, are now able to access the contents in a seamless and interactive way and can organise the information according to their informational and research needs.

Although the organisation of the digital information, e.g. in the databases or the georeferencing systems, implies a fixed and hierarchical structure, the hyperlinks offer, on the contrary, much freer access to cultural knowledge. This information is spread and increased through channels and methods that are unpredictable for those planning the online cultural services.

The hyperlinks enable a new way of systematizing and enriching cultural information, speeding up contacts across many different content sources and fostering a new circulation of knowledge.

The extensive digitisation and rich cataloguing of digital cultural material provides flexible tools and assets, allowing us to merge and integrate different sources of information, even if they are physically separated and under the responsibility of distinct institutions under different jurisdictions. They can therefore be made available to a wide public who can interconnect them by fully exploiting the potential offered by the Web.

If, according to sociological studies, the Web might be interpreted as something which exists in opposition to direct experience and as something which has fragmented reality (Bauman, 2002, pp. 249-250), the contrary is true in the cultural field: in relation to cultural heritage, the Web allows us to re-assemble and reconstruct evidence that is fragmented, separated or far away and hard to reach in the physical world, and enables the confluence of diverse sources of knowledge.

Digitisation thus offers a new way of re-creating physical evidence.

Moreover, the Web provides institutions with new opportunities to come into contact with a wide ranging non specialist public. It assists those who are looking for direct contact and enjoyment of physical cultural assets, to prepare themselves in advance to any visit and, afterwards, to deepen their knowledge of these cultural objects later, given that digital documents, produced by cultural institutions, are more flexible and adaptable to personal needs than traditional printed ones.

The online publication of digital cultural content is an innovation which will allow the users of cultural information to grow both in number and expertise.

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## VENUS (Virtual ExploratiON of Underwater Sites) Two years of interdisciplinary collaboration.

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### ABSTRACT:

This article describes on-going developments of the VENUS European Project (Virtual ExploratiON of Underwater Sites, <http://www.venus-project.eu>) over its first two years of activity. The VENUS project is a collaborative venture which aims to bring together archaeological and scientific methodologies with technological tools for virtual exploration of deep underwater archaeological sites. The breadth of results produced by the project allow us to give only an overview of the key issues here.

The techniques developed through the work of the project are firmly rooted in the requirements of the archaeologists involved. The on-going relationship between archaeological requirements and technological solutions developed in response to them forms the core of the project. In this article we will describe the evolution of both the archaeological methodologies and the technical solutions that were developed to support them during the first mission of the project – at Pianosa Island, Italy in October 2006 - and in the subsequent activity, including the second mission to Sesimbra, Portugal in October 2007, and the preparation of the third one, to Marseille, France, at the end of 2008.

Realising the integration of the acoustic data stream with the optical data acquisition has formed a major component of the first two years of the project. Acoustic sensors track the position of unmanned underwater vehicles, like ROVs and AUVs, while they collect images during a site's survey. The fusion of acoustic and navigation data provides the seed for the photogrammetric process, recording cameras' position and orientation in real time within the EXIF metadata of the images.

In response to archaeological requirements the representation of the data takes two distinct forms. The first being a traditional two-dimensional representation, conforming to the illustrative norms of archaeological cartography, providing a rich interface to the extensive underlying archaeological datasets. The second representation is a three-dimensional visualization of the site. By using an augmented reality system, we are able to make available for archaeological investigation complex datasets in the accepted, traditional, two-dimensional form, as well as to produce three-dimensional interfaces which provide new insights on archaeological data.

In order to represent the archaeological information, we consider a knowledge base consisting of application ontology and observations. We constructed application ontology for underwater archaeological knowledge.

Throughout the course of data acquisition, processing and delivery, the project has addressed the need for long-term preservation and access to the dataset. By identifying specific digital preservation requirements, the aim is to produce guidelines for the archiving of material derived from future investigations.

The project will conclude with a final field mission near Marseille, France, utilising all the techniques developed to undertake a fully automated diver-less survey of a deep-water wreckage site. The culmination of the project will realise the desire of archaeologists and of the general public to make possible the interaction with an underwater site that is out of the physical reach of the common diver.

### 1. INTRODUCTION

The VENUS project is funded by the European Commission, Information Society Technologies (IST) program. It aims at providing scientific methodologies and technological tools for the virtual exploration of deep underwater archaeological sites (Chapman et alii, 2006).

Underwater archaeological sites, for example shipwrecks, offer extraordinary opportunities for archaeologists due to factors, such as darkness, low temperatures and a low percentage of oxygen, which are favourable to preservation. On the other hand, these sites cannot be experienced firsthand and are continuously jeopardized today by activities such as deep trawling that destroy their exposed layer.

The VENUS project will improve the accessibility of underwater sites by developing tools and methodologies for constructing thorough and exhaustive 3D archives for virtual exploration.

The project team plans to survey shipwrecks at various depths and to explore advanced methods and techniques of data acquisition by means of autonomous or remotely operated vehicles (ROVs) equipped with acoustic and photogrammetric devices. VENUS research also covers aspects such as data processing and storage, plotting of archaeological artefacts, information system management and best practices and procedures for underwater cultural heritage.

Further, VENUS will develop virtual reality and augmented reality tools for the visualization of an immersive interaction with digital models of underwater sites. Models will be made accessible online, both as an example of digital preservation and for demonstrating new facilities of exploration in a safe, cost-effective and pedagogical environment. Virtual underwater sites will help archaeologists to get a better insight into the data and they will let the general public experience simulated dives to the sites.

The VENUS consortium, composed of eleven partners, is pooling expertise from various disciplines: archaeology and underwater exploration, knowledge representation and photogrammetry, virtual reality and digital data preservation.

## 2. THE UNDERWATER ARCHAEOLOGICAL SITE OF PIANOSA ISLAND

This Section focuses on the first experimental sea trial in the project that has taken place in Pianosa Island, Tuscan Archipelago, Italy, on October 2006. Pianosa Island belongs to the Tuscany Archipelago, North Tyrrhenian Sea, Western Mediterranean. The underwater archaeological site of Pianosa, discovered in 1989 by volunteer divers, is located at a depth of 35 m, close to the “Scoglio della Scola”, in front of the east coast of the island. The site, mainly untouched, is characterized by the presence of about one hundred amphorae of different origin and epochs. The various amphorae range from Dressel 1A (1<sup>st</sup> century B.C.) to Beltran 2 B and Dressel 20, up to African models (3<sup>rd</sup> century A.D.). The Iberian amphorae (Dressel 2-4, Pascual 1, Beltran 2 B) are predominating and they come either from northern Spain (*Tarraconensis*) or from southern Spain (*Baetica*). The site has been chosen as an operative test-bed for the VENUS project since its depth allows to survey the area using both robotic equipment and divers.

## 3. PHOTOGRAMMETRIC SURVEY IN PIANOSA

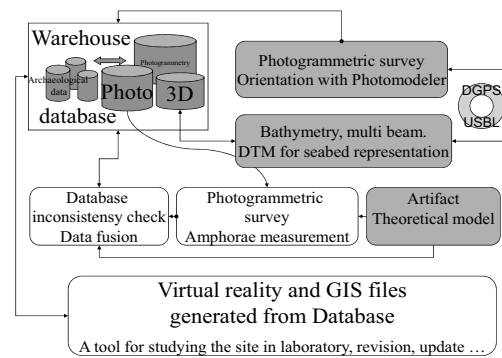


Figure 1: Synoptic scheme of surveying, data handling and rendering process.

The main goal of the experimentation at Pianosa was to provide photogrammetric data complemented by additional information (as bathymetry and seabed morphology, described by a Digital Terrain Model (DTM), obtained from acoustic and optical measurements) and properly georeferenced by the combined use of an underwater acoustic positioning system (USBL – Ultra Short Base Line Systems) and a Differential GPS.

The material produced during the entire survey has been stored in a suitable relational database. The database structure allows comparison of the findings with theoretical models of the amphorae to remove data inconsistencies and artefacts, eventually leading to 3-D models that can be exported toward Virtual Reality environments. This approach will allow archaeologists to see the entire site, using immersive VR technologies, without diving (Drap et alii, 2005), (Gambogi et al, 2001). A synoptic scheme summarizing the entire process is depicted in Figure 1.

### 3.1 Two different ways for data capture

The photogrammetric survey in Pianosa has been planned in order to obtain a sequence of photo over a linear strip, with an appropriate forward overlap (60%) between two subsequent photographs. Once a strip has been completed, an adjacent strip is surveyed, with 20% lateral overlap with respect to the previous strip. The procedure is very similar to the one used in aerial photogrammetry; the main difference being the distance to the seabed and the presence of the water. The bathymetric variation could also be in general an important difference, but not at the Pianosa site, where the seabed in the working area is almost flat.

The Pianosa test-site offered the opportunity to test and compare different ways to conduct the survey. In particular the site was surveyed both by divers (CNRS partner) and by a ROV, a robotic vehicle linked through an umbilical cable to the surface ship, and operated in a semi-automated modality (ISME partner)(Conte et al. 2007).

The diver used a Nikon™ D70 digital camera with a 14 mm lens from Sigma™ and two flashes Subtronic™. (Drap,et al. 2007) The digital camera was embedded in Subal™ housing with a hemispherical glass. The ROV was equipped with a system provided by the COMEX partner and consisting of a Nikon DH2 digital camera, a 14 mm lens from Sigma™ and

two flashes Nikon™ SB800, with custom-made housing and connectors (See Figure 2).



Figure 2: The ROV in the water with digital camera and flash lights in their housing; left: side view of the ROV; right: view from the seabed upward. The flash lights are on the side of the camera.

The working area has been delimited by archaeologist, that also deployed 4 scale bars (2m each) and a set of 15 markers (concrete blocks 15x15x10cm) in order to define a grid for ROV guidance. The working area was surveyed by the ROV, strip by strip, at fixed altitude over the seabed (Conte et al, 2007). With the ROV system, the photogrammetric data were collected in two different modalities:

- manually, through a command from the surface ship transmitted via the umbilical cable; a small video camera installed through the lenses allowed the operator to look at the scene with the same view of the camera and to activate the acquisition command. In this modality the archaeologist on board the ship can have full control of the acquisition operation without actually diving over the site.
- In automatic mode, with a fixed frequency rate, selected taking into account the flash recharge time and the ROV speed and altitude. An example of two consecutive shots from the ROV automatic modality is reported in Figure 3.

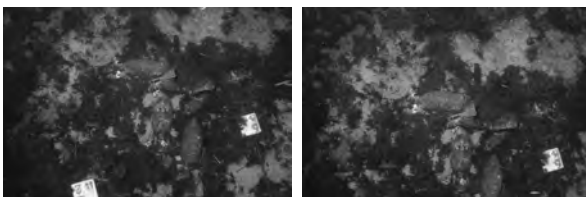


Figure 3: Two photographs from a strip made by the ROV.

### 3.2 Multimedia photogrammetry calibration

Camera calibration in multimedia photogrammetry is a problem identified since almost 50 years. (Bass et al, 1973), (ASP, 1980). The problem has no obvious solution, since the light beam refraction through the different media (water, glass, air) introduces a refraction error which is impossible to express as a function of the image plane coordinates alone (Mass, 1995). Therefore the deviation due to refraction is close to that produced by radial distortion even if radial distortion and refraction are two physical phenomena of different nature. For this reason, the approach described by Kwon (Known, 2000) has been adopted, consisting in the use of standard photogrammetric calibration software to perform the calibration of the set housing + digital camera. This approach can indeed correct in a large part the refraction perturbation; however, it is strongly dependent on the optical characteristics of the water/glass interface of the housing. In order to minimize the refraction error due to this last interface, a housing with a hemispherical glass (Subal™) has been selected for the divers-operated camera. The same housing, however, could not be

accommodated on the COMEX developed system, due to the mechanical constraints imposed by the additional instrumentation and electronics for the automated mode operation. Hence in this latter case the housing glass was plane and the refraction action, even after calibration, is much more relevant. A specific method to compensate separately refraction and distortion has been developed, but its description is beyond the scope of this paper. The interested reader can find it as a deliverable of the VENUS project downloadable from the VENUS web site <http://www.venus-project.eu>.

### 3.3 The reference system

A fundamental aspect in any survey procedure is the choice of a reference system for the acquired data. The choice may be driven by the archaeological needs and by the available instrumentation. In general, two choices can be considered: a relative reference system, and an absolute georeference system. The relative reference system is the option mostly used in underwater photogrammetric work: the reference system is defined from the data themselves exploiting locally observable geometric features of which the prior orientation and dimension is known, as buoys to define the vertical axis, scale bars, etc. In most cases this approach requires preparation of the site with the deployment of appropriate reference objects and tools by means of divers. This may be a costly, time-consuming operation, possible only at working depths for divers (about 60m).

The use of a robotic vehicle allows to obtain automatically a set of georeferenced positioning data that can be exploited in the photogrammetric process. In particular, in the Pianosa experiment ISME ROV was equipped with a USBL acoustic positioning system, consisting of an acoustic transducer, deployed from the side of the supply ship, and a transponder on the ROV frame. The acoustic pings transmitted from the surface ship are reflected by the transponder; by evaluating the time of flight and the direction of arrival of the reflected signal, the system produces an estimate of the position of the ROV with respect to the transducer. Merging this information with Differential GPS data, taking into account the displacement between the DGPS receiving antenna and the transducer position, allows to estimate the ROV position in geographical coordinates. In addition, the ROV is also equipped with inclinometers, compass and accelerometers: this allows to determine the orientation (roll, pitch, yaw) of the ROV, hence of the high resolution camera, taking into account also in this case the geometry of the system, i.e., the displacements between camera and sensors position. Additional sensors, including depthmeter (pressure gauge), altimeter (echosounder), encoders on the thrusters' shafts, are mounted on the ROV and their measurements are recorded for post-processing and validation purposes.. The Navigation, Guidance and Control (NGC) system, which governs the ROV and its sensory apparatus, associates to each photograph a set of navigation data, including in particular the georeferenced position of the camera and its orientation.. Integrated optical/navigation data are directly stored in JPEG/EXIF format. The processing flow of the system is illustrated in Figure 5. It is interesting to note that the USBL system has been employed also to track the absolute position of the divers during the "traditional" human-based acquisition test. In the photogrammetric processing, the error is taken into account by using ROV navigation data as approximate values to initialize a bundle adjustment.

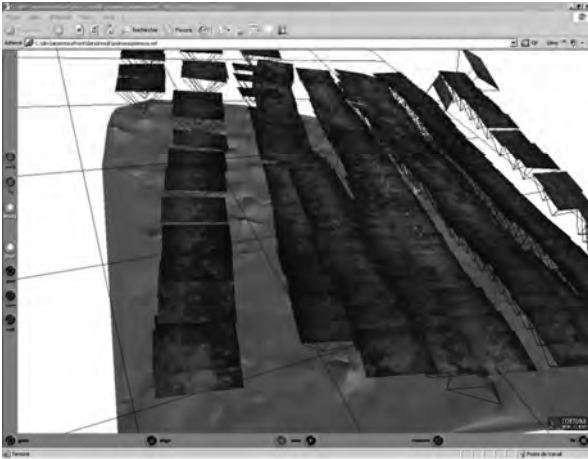


Figure 4: Oriented photographs visualised in VRML with the non textured seabed measured with photogrammetry

The whole photogrammetric processing is conducted by means of the commercial software Photomodeler™, with user's supervision to correct the initial orientation errors. An example of the final oriented photographs, georeferenced and superimposed to georeferenced bathymetry of the area, is shown in Figure 4.

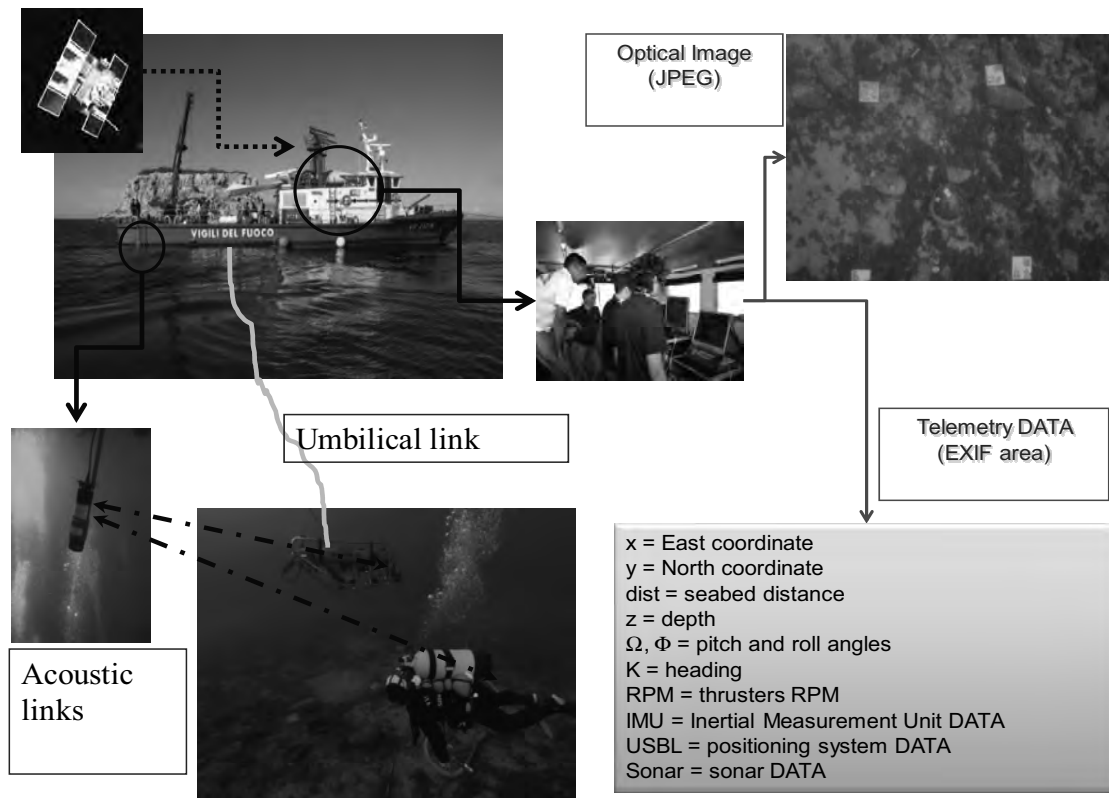


Figure 5: Pipeline for tagging photograph with navigation data.

### 3.4 Amphorae plotting

From the oriented photographs, a subsequent 3D geometrical modelling phase of the recorded artifacts (amphorae in our case) is started. In this phase the modelling must be driven by expert (archaeological) knowledge; the resulting models, together with the photogrammetric georeferenced data and all the survey data, is stored in a repository database for further use and interrogation.

The 3D modelling phase procedure consists in exploiting archaeological knowledge to obtain a complete representation of the measured artefact; it is articulated in two steps:

- 1) Development of the theoretical model: for each identified object, a geometrical description offers a set of geometrical primitives, which are the only features to be potentially measured; these are compared with the theoretical representation of the object as derived from expert knowledge. In our case archaeologists have identified six amphora typologies, and a theoretical model is produced for each of

them. This theoretical model is formalized in a hybrid way, taxonomy of archaeological artefacts and XML representation for the amphora typology.

2) As photogrammetric measurements are highly incomplete (the object is seen only partially or may be deteriorated), an Expert System determines the best strategy to provide all the geometrical parameters of the studied object, starting from the measurement process and handling the default data as defined in the archaeological model and the geometrical model. In our case, we are using the Jess expert system (<http://herzberg.ca.sandia.gov/jess/>).

The resulting object is thus based on a theoretical model, dimensioned by a photogrammetric measurement. The modelling procedure is revisable in time, allowing re-processing or complementing the processing as new data may become available. The whole procedure has been implemented in Java and connected to the *Arpenteur photogrammetric toolbox*. (Drap et al. 2005).

Amphorae classification in archaeological work does rely very strictly on dimension information on specific features of the object, as for instance the neck. In providing a theoretical model for a specific amphora class, it does make sense to measure these features directly on an available archaeological site. At the Pianosa site, six amphorae have been resurfaced by the divers. These amphorae are used as paradigm to define the needed theoretical model. Since they do not account for all the classes of amphorae observed at the site, the direct observation of the finds is complemented with drawings and information from archival data; for instance, type gauloise 3 is modelled accordingly to the typology presented by Archaeological Data Service, University of York, also partner in VENUS ([//ads.ahds.ac.uk/catalogue/archive/amphora\\_ahrb\\_2005/details.cfm?id=135](http://ads.ahds.ac.uk/catalogue/archive/amphora_ahrb_2005/details.cfm?id=135)).

In defining the theoretical model, the diversity of the objects handled by the archaeologists and the geometric complexity of their surfaces led us to search for stable morphological characteristics of the objects where diagnostic measurements could be taken. A series of simple geometric primitives are used to approximate these morphological characteristics and are used as an interface between the photogrammetric measurement and the underlying model. In the case of amphorae, four measurable zones have been defined: rims, handle, belly, bottom. A set of simple geometrical primitives is fitted by least square method onto the measured points: for instance a circle on the rim or belly points, a line on bottom point, etc... This interface allows the user (generally an archaeologist) to

- Recognize the amphora type on the photographs;
- Choose the amphora type in the interface combo box;
- Measure a set of points on the zone where measure is allowed;
- Add archaeological comments and observations;
- Derive a model from the object, using the measured points to construct a new instance of amphorae;
- Insure consistency between observations and theoretical model;
- Store a new instance in the database.

#### 4. MERGING RESULTS

Bathymetric data and photogrammetric data have been merged, exploiting the georeferencing of both acquisition systems and the orientation adjustments in the photogrammetric processing, and eventually linked to the Amphorae representation in the database. The data base is organized as a relational database (MySQL) and a set of java tools allows to wrap objects from the database and to produce a VRML representation.

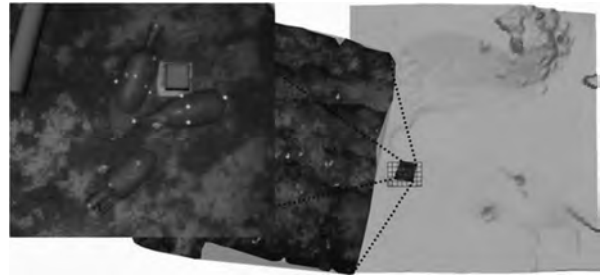


Figure 6: VRML representation of reconstructed amphorae. From right to left: general area bathymetry with the location of the archaeological site superimposed; a blow up of the experimental site; a blow up on a specific portion of the site, with amphorae entirely reconstructed using the modelling information. Also visible the measured points on amphorae, and the geometrical models of a concrete marker (red square) and two scale bars (red and white cylinders).

The VRML file produced contains a link for every amphora to the database via a PHP interface. This interface allows the user to see, check and modify the archaeological values regarding the amphorae. Of course the user has access to all the data, i.e. measuring points, photos and photo orientation used to measure the artefact, but these data are read only through the interface.

#### 4.1 Accuracy

A set of observations of homologous points on photographs are measured manually in order to orient all the photographs in a local reference system. Then we use the camera position given by ROV navigation data which are in the absolute reference system consistent with the multibeam data. In Figure 4, an example is given of the final result: a 3D model of the seabed is obtained, over which oriented photographs are superimposed.

The availability of acoustic bathymetric data from the multibeam survey allows for a comparison with the final 3D model obtained with the photogrammetric approach. It has to be mentioned however that the resolution of the multibeam survey is of the order of 1 sample every 0.5m, over a large area, while the resolution of the photogrammetric data is approximately 1 sample every 0.01 m over a much smaller area. The discrepancy between the DTMs obtained from the multibeam survey and the photogrammetry in the Z direction shows a mean systematic error of 0.502 m with an RMS of 0.073 m. It is not possible to determine the discrepancy of the merged data in XY as the seabed is flat in this zone (see Figure 6). This will be estimated from the absolute accuracy of the measurement techniques.

These discrepancies are indeed compatible with the respective accuracy of each sensor, and in fact may indicate that the photogrammetric processing does not introduce any additional uncertainty larger than those of the navigation sensors.

### 5. CURRENT DEVELOPMENT: GIS FRAMEWORK

In the context of archaeological survey, 2D representations are well known and largely used by archaeologists. These representations can be handmade drawing or digital maps. Postprocessing all the data collected on the site and using the resulting information (ROV navigation data, oriented photographs, seabed DTM, 3D artefact reconstruction, and so on.) we can build automatically a GIS representation of the surveyed site.

The use of a 2D GIS representation is possible since we are dealing, in the VENUS project, with the surface layer only of the explored sites and it has two advantages:

- the 2D representation is convenient for archaeologist needs;
- the GIS enables to augment simple maps by additional information

The GIS representation we consider relies on the standard formats GeoTIFF and Shapefile (Shapefile is a geospatial vector file format from ESRI™ company, but an open source specification of it is available and it is used in several open source software development projects).

The Shapefile format covers simple 2D geometric representation and it is suitable for a schematic representation of the measured objects. The GeoTIFF format enables to store georeferenced images.

### 5.1 Archaeological database

The archaeological database registers the 2D and 3D points of artefacts lying on the seabed, measured during the photogrammetry process. When those points are labelled as belonging to a recognized artefact type, an actual artefact could be reconstructed taking into account location, orientation and size of the measured object. All the parameters involved in the process are registered in the database so to make the information available both for the photogrammetric reconstruction and the design of the virtual environment reproducing the site.

## 6. ARCHAEOLOGICAL ONTOLOGY

In order to represent the archaeological knowledge obtained by means of the photogrammetric process, a suitable ontological approach has been considered. The first question in its definition concerns the kind of ontology that may better represent underwater archaeological knowledge. In the context of the VENUS project, photogrammetric technologies are used for data acquisition and the knowledge provided relates to underwater archaeology but also to data the acquisition process. According to the Guarino's classification of ontologies (Guarino et al. 1995), the underwater archaeological knowledge could be captured by a domain ontology that describes the vocabulary relating to amphorae, while the knowledge relating to photogrammetric data acquisition process could be captured by a task ontology. Consequently, we constructed an application ontology to represent underwater the archaeological knowledge provided by photogrammetry.

The application ontology, denoted by  $O$ , can be formalized by  $O = \{C, Hc, D, R, Co\}$  where  $C$  is the set of concepts derived from the set of classes of the ARPENTEUR software,  $Hc$  is the hierarchy of concepts,  $D$  is the set of domains corresponding the concepts attributes. For example, a domain can be a set of numeric values for the POINT, METROLOGY, POSITION concept attributes, or an enumerated list of values for the AMPHORA ITEM concept attributes.  $R$  denotes the set of non specialisation relations between concepts, like aggregation relations.  $Co$  denotes the set of constraints between concepts or/and between attributes and concepts, like cardinality constraints, real world constraints, conditional constraints: constraints between amphorae typology and dating or amphorae metrology and dating, for example, and spatial constraints.

A reference model, the CIDOC-CRM ontology (Crofts et al. 2008), which is a domain ontology and which now is an international ISO standard (ISO 21127:2006), has been developed for traditional archaeological activities. However, when using new

technologies, the construction of an application ontology taking into account a task ontology requires some extensions of the CIDOC-CRM ontology (Jeansoulin et al. 2007).

Within this framework, a knowledge base can be defined by the set  $KB = \{O, I, instc, instR\}$  where  $O$  denotes the application ontology defined above representing the generic knowledge,  $I$  denotes the set of instances, i. e. the observations and  $instc$  resp.  $instR$  denote the instantiation functions on the concepts, respectively on the relations, of  $O$ . Because of errors during the acquisition process, inconsistency may result and consistency has to be restored.

The knowledge base provides a partial preorder, and we first investigated consistency handling partially ordered information, when the knowledge base is represented in propositional logic. We extended the Removed Sets approach (Bennaïm et al. 2004), initially defined for non ordered or totally ordered knowledge base, to partially ordered propositional knowledge base and proposed an implementation stemming from answer set programming (Serayet et al. 2008).

Since several observations can be performed by different actors at different times we extended the Removed Sets approach to the fusion of proposition knowledge bases. We implemented the Removed Sets Fusion with answer set programming and provided an experimental study (Hue et al. 2007).

## 7. VIRTUAL AND AUGMENTED REALITY

Besides the classical representation described above, the VENUS project offers new modalities for both archaeologists and general public to exploit or explore the underlying archaeological datasets through extensive use of Virtual and/or Augmented Reality.

The base idea behind using VR and AR techniques is to offer archaeologists and general public new insights on the reconstructed archaeological sites allowing archaeologists to study directly from within the virtual site and allowing the general public to immersively explore a realistic reconstruction of the sites. Both activities are based on the same VR engine but drastically differ in the way they present information. General public activities emphasize the visually and auditory realistic aspect of the reconstruction while archaeologists activities emphasize functional aspects focused on the cargo study rather than realism



Figure 7: Archaeologists (top) & General Public (bottom) VR demonstrators

### 7.1 Augmented Reality for archaeologists

Since archaeologist's interest is mainly focused on the nature of the cargo, one of the first feedbacks from archaeologists concerning VR Venus was that immersive navigation didn't provide much help to archaeological tasks, in opposition to general public concerns, where immersive navigation provides a deeper experience of a site. This observation led us to propose a map based navigation paradigm, such as the "World in Miniature" proposed by Stoakley et al (Stoakley et al. 1995) and later applied to Augmented Reality by Bell et al (Bell et al. 2002), which provides a much more familiar interface to archaeologists. Moreover, the Augmented Reality paradigm offers the opportunity to introduce a tangible interface proposed by Ishii & Ullmer (Ishii et al. 1997) and Poupyrev et al. (Poupyrev et al. 2001) to the tools developed in the VR demonstrator for archaeologists. These elements lead to the definition of a new demonstrator for archaeologists: AR Venus.



Figure 8: AR Venus.

AR Venus is the Augmented Reality version of VR Venus designed to closely fit archaeological needs based on the first feedbacks from archaeologists on VR Venus. In AR Venus, archaeologists visualize a 2D map representing the site. Archaeologists have more facilities to work with maps where they can see the real world rather than a totally immersive environment in which it is difficult to be localized. Rather than to immerse the archaeologist in a completely simulated artificial world, AR Venus proposes to enrich the environment and complete the real-world perception by adding synthetic elements to it. AR Venus provides an easy tool to interact with the real-world using tangible interface to select and manipulate virtual objects with accuracy, using effective pose estimation algorithms to project synthetic models at the right location on the 2D map. Users need to wear special equipment, such as see-through head-mounted display, to see the world around them, augmented in real time with computer-generated features (see Figure 8).

### 7.2 Virtual Reality for the general public

The danger with a project such as VENUS is to generate large quantities of data that is relevant solely to archaeologists. With so many areas of expertise involved in VENUS it is not just the artefacts that are of interest. The final interface to our archaeological database is aimed at creating awareness of both the artefacts that were found and of the process by which they were discovered.

The general public interface recreates the dive process from ship to seabed, allowing members of the public to experience the exploratory process first hand. We allow the general public to assume the role of a virtual submarine operator, giving them the task of uncovering the archaeological sites themselves.

The vast quantities of data generated from both the initial surveys and their consequent analysis provides us with the ability to accurately model the location of the dive sites. By combining this geometry with our custom underwater render engine we are able to create an interactive and realistic reproduction of both the environments and artefacts.

We further enrich the dive simulation by linking it to additional textual and photographic records. As the interface gathers data directly from our archaeological database we also get access to the notes and interpretations made by archaeologists. By presenting this information at key points during the dive simulation we present the public with the opportunity to learn about each stage of the dive. We hope that by presenting VENUS in this way we can capture the imagination of the general public in a way that simply couldn't be achieved using traditional methods of dissemination.

## 8. DATA PRESERVATION

Throughout the course of data acquisition, processing and delivery, the project has addressed the need for long-term preservation and access to the dataset. By identifying specific digital preservation requirements, the aim is to produce guidelines for the archiving of material derived from future investigations.

There are four main aspects of this area that are considered in the VENUS Project. First, to refine digital preservation techniques, so that they can be readily applied to the unusual range of data formats captured during underwater archaeological investigation. In doing this we should ensure that partners within the consortium learn about digital preservation. Beyond the VENUS partnership we also aim to promote best practice in digital preservation through publication of a short practical guide based on this shared experience. And finally, during the life of the project, we hope to adopt and test those best practice and techniques.

The first stage in addressing these aspects was to undertake a comprehensive desk-based study of the data lifecycle of the project, from data acquisition, through post-processing (including photogrammetry) to dissemination via various VR techniques, and ultimately to its long-term storage and accessibility to future scholars. This study was started prior to the first VENUS mission (Pianosa, Italy) as it concerned generic technologies and their data outputs and formats. Elements of the study were significantly informed by the work carried out by the partner ADS, relating to formats and metadata for large scale bathymetric survey, as part of the English Heritage funded *Preservation and Management Strategies for Exceptionally Large Data Formats: 'Big Data'* project (<http://ads.ahds.ac.uk/project/bigdata/>).

Close collaboration between the ADS and other VENUS partners was required to develop a comprehensive picture of the data lifecycle of the project. To this end the ADS undertook a data audit of the digital outputs of the first underwater mission, working with partners at ISME, looking in detail at the processes of data acquisition and the immediate processing and sampling that is carried out as the survey is undertaken. The breadth of the potential dissemination modes for the project were considered in collaboration with colleagues at the University of Hull – assessing incoming and outgoing file

formats and the variety of VR dissemination hardware and solutions available.

What became clear from this work is that both the level and scope of the metadata generated during data capture are high, and that much of this metadata is critical to the later stages of the lifecycle (photogrammetric modeling and VR model generation). Devising a comprehensive archive and dissemination strategy to encompass the complexity of this dataset presents a distinct challenge.

It is apparent that the VENUS Project data lifecycle (and therefore other, similar, complex data acquisition and processing cycles) represents a series of sophisticated data transitions. The data preceding and following each transition stands, with its associated metadata, as a coherent dataset, embodying the previous transitions and the techniques employed during those transitions. Each of these points represents an opportunity to archive the data. We have termed these 'candidate Preservation Intervention Points'. If the data at these points is to be included in a digital archive, and it become a true Preservation Intervention Point (PIP), a number of criteria must be met: the accompanying metadata must be sufficient for preservation purposes (allowing any anticipated reuse of the data in the future); there must be suitable resource discovery metadata associated with the data; the data at this point should have either a known re-use case, or a strong potential re-use case; and the repeatability and value of the previous data transitions must be assessed.

Measuring concordance with the metadata requirements is relatively straightforward, but understanding the re-use potential, repeatability and inherent value of the processed data is most appropriately left to those with particular expertise in handling the data at each stage. To guide this process the project is developing a decision tree which will act as a tool for VENUS data managers to use in determining the most suitable stages at which to archive the dataset.

These Preservation Intervention Points are non-exclusive and the archival process should be non-proscriptive in the selection of data for inclusion. It is hoped that this will increase the engagement of the data producers in the archival process, helping to ensure the future usefulness and value of the archived material.

## 9. CONCLUSIONS AND FUTURE WORK

Archaeologists need to explore and make an inventory of deep wreckage sites, which are unreachable by divers, since those sites are jeopardized by deep trawling and other off-shore activities and they risk to be destroyed in the very next few years. The digital preservation aspect is one of the main goals of this project.

A methodology for underwater survey and data processing - involving the complete processing flow: from georeferenced data acquisition in semi-automatic mode to merging acoustic/optical data with a theoretical model including archaeological knowledge and to site reconstruction in virtual and augmented reality - has been developed in the framework of VENUS and presented here.

A first draft of a 2D GIS application has been proposed and used for testing. The geometric-database link and an automatic transfer from 3D representations to 2D standard GIS formats have been implemented. Enhancements of the GIS capabilities are planned.

The second VENUS mission has taken place in Sesimbra, Portugal on a wreck at about 60m depth, on October 2007. The survey was made both by divers and ROV. The next VENUS mission is scheduled in October 2008. It will take place in

Marseille, France, over a shipwreck lying at a depth of about 100m. That mission will not involve divers and it will serve to test a fully automatic procedure to gather and process submarine navigation data with photogrammetry.

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# **Virtual Reality Applications in Cultural Heritage**



# VIRTUAL REALITY TECHNOLOGY IN MUSEUMS: AN IMMERSIVE EXHIBIT IN THE “MUSEO LEONARDIANO”

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**KEY WORDS:** Virtual Reality, 3D animation, VR museum exhibits, Leonardo da Vinci, 3D historic reconstruction, portable immersive systems

## ABSTRACT:

In this paper we describe the design and development of an interactive, immersive installation created for the Museo Leonardiano (Leonardo's museum) in Vinci, Italy. The exhibit was part of a series of events aimed at celebrating Leonardo da Vinci's Genius and its specific purpose was to let the viewers visualize and experience Leonardo's visionary concept of an infinite, heliocentric universe (anticipatory of the Copernican System) as opposed to Ptolemy's model of a finite, geocentric world. The viewers were first immersed in a 3D synthesized geocentric universe and taken through a virtual journey across the eight spheres of Ptolemy's cosmological model. Then they travelled through Leonardo's heliocentric world and explored it from unique points of view. In the first journey the visitors perceived the cosmos as a closed, static entity, whereas in the second voyage they experienced Leonardo's revolutionary concept of an open, dynamic universe part of an infinite space. The interactive exhibit was based on the use of Virtual Reality (VR) and 3D Animation technologies. The hardware setup consisted of a single-screen portable immersive system with head and hand tracking technology and passive stereo. The visual content included 3D renderings of Ptolemy's and Leonardo's universes designed, modeled and animated by the authors in Autodesk Maya software. The audience reactions and comments demonstrated the effectiveness of the technology for visualizing the two systems and for conveying the contrast between the two cosmological models. The project described in the paper had two higher objectives. The first goal was to investigate the potential of VR technology as an educational/entertainment tool and as an instrument of historic research, simulation, reconstruction and dissemination in museums. The second objective was to initiate research toward the design of a novel museum space and technological infrastructure to support the development and display of VR immersive exhibits in the Da Vinci museum.

## 1. INTRODUCTION

In this paper we describe the design and development of an interactive exhibit created for the Museo Leonardo da Vinci in Vinci, Italy. The exhibit was part of a series of events called “Celebrazioni Leonardiane” (May 2008 - July 2008) that took place in various locations in Leonardo's home town. The events included cultural, scientific, educational, artistic, and entertainment activities which aimed at celebrating Leonardo's visionary ideas in a variety of fields spanning engineering, science, art, anatomy, mathematics, and astronomy. The emphasis of the “Celebrazioni Leonardiane” was on the dissemination of many aspects of Leonardo's work that are still under study and exploration and, therefore, not fully known to the general public. The specific objective of the exhibit described in the paper was to visualize Leonardo's intuition of a heliocentric, infinite universe in opposition to Ptolemy's theory of a geocentric system.

The interactive installation made use of 3D animation and VR technologies because of their advantages over traditional media and 2D multimedia. VR-based museum exhibits have gained popularity in recent years and a few examples have been reported in the literature (Hirose, 2007) (Roussou, 1999). Researchers argue that VR installations offer several benefits over more traditional museum exhibitions (Roussou, 2007) (Youngblut, 1997). These advantages, discussed in detail in section 3, include: a more effective way of communicating the scientific results of historical investigations through photorealistic reconstructions of places and people that no

longer exist or may not be easily experienced; intuitive visual representation of abstract concepts, systems and theories that would be difficult to communicate with diagrams, textual descriptions and static images; and enhanced viewer's engagement and motivation through high level of interactivity and “immersion”. Immersion is defined as “the illusion of being in the projected world.. surrounded by images and sound in a way which makes the participants believe that they are really there” (Roussou, 2001).

These reported strengths have motivated the choice of VR technology as the base for our exhibit which is the first example of VR installation in the museo Leonardiano. The visitors' comments have confirmed the effectiveness of VR and 3D animation technologies for communicating Leonardo's vision.

The full paper is organized as follows: In section 2 we describe Leonardo's visionary concept of a heliocentric infinite universe. In section 3 we give an overview of virtual reality technology, we report examples of VR museum exhibitions, and we discuss the potential of VR as a tool for research, visualization and education in informal settings. Detailed descriptions of the installation including the immersive system, the animated models, the architectural setting, and the viewer's interaction experience are presented in section 4. Discussion and conclusive remarks are included in section 5.

## 2. LEONARDO'S UNIVERSE

Ptolemy's geocentric model of the universe was the accepted cosmological system during Leonardo's times. It was based on the theory that the earth is at the center of the universe and the sun and other objects go around it. Belief in this system was common in ancient Greece and was embraced by many medieval astronomers and philosophers. In the first book of the *Almagest* (Encyclopedia Britannica, 1952), Ptolemy described his geocentric model and gave various arguments to prove that, in its position at the center of the universe, the spherical earth must be immovable. Ptolemy's system consisted of a series of concentric spheres containing the celestial objects positioned in the following order: earth, moon, mercury, venus, sun, mars, jupiter, and saturn. The heavenly bodies moved along deferents, large circles centered on the earth, and epicycles, small circles whose centers moved around the deferents. The sun, moon and planets moved along the circumference of their own epicycles; the universe ended in the sphere of the "fixed stars". Beyond were two crystalline spheres and an outer sphere named the "primum mobile" or first motion, which was circumscribed by the "coelum empyreum", of a cubic shape, wherein happy souls found their abode (Polaris Project, [http://www.polaris.iastate.edu/EveningStar/Unit2/unit2\\_sub1.htm](http://www.polaris.iastate.edu/EveningStar/Unit2/unit2_sub1.htm)). Ptolemy's theory, which was able to justify the presence of the celestial bodies and their apparent motion around the earth, resulted in the conception of a finite, limited universe defined by a very rigid sequence of concentric vaults.

Leonardo was interested in astronomy and anticipated several fundamental concepts which are reported in: "Studies on the dimensions of the Earth and Moon in relation to the Sun" (see figure 1), in his drawings of the moon, in "Notes on the illumination of the moon", and in his studies on the heat of the sun and scintillation of the stars (Leonardo da Vinci, Codex Hammer). Of all his intuitions, the most revolutionary was the one related to the centrality of the sun. While Leonardo's early reflections of 1482-1500, contained in the Codex Atlanticus (Leonardo da Vinci, Codex Atlanticus), Arundel (Leonardo da Vinci, Codex Arundel), Hammer (Leonardo da Vinci, Codex Hammer), and F (Leonardo da Vinci, Codex F) show adherence to Ptolemy's theory: "*il Sole che scalda tanto mondo quant'è vede, e che in 24 ore fa sì gran corso*" (Codex Atlanticus, f. 30v), his later writings demonstrate his rejection of the geocentric system: "*Come la Terra non è nel mezzo del cerchio del Sole, né nel mezzo del mondo, ma è ben nel mezzo de' suoi elementi, compagni e uniti con lei, e chi stesse nella Luna, quand'ella insieme col Sole è sotto a noi, questa nostra Terra coll'elemento dell'acqua parrebbe e farebbe ofizio tal qual fa la Luna a noi*" (Codex F, f. 41v) (Calanca, 2007).



Figure 1: Leonardo's drawing: "Annotazioni non organiche sulla Terra e sulla Luna, con particolare riferimento alla loro dimensione ed al rapporto col Sole" (Leonardo da Vinci, Codex Hammer) © Istituto e Museo di Storia della Scienza

Leonardo realized that the earth is a planet which reflects light, moves around its own axis, and is subject to a continuous cycle of geological transformations. Further, in the W.L. manuscript (f. 132r) (Calanca, 2007) Leonardo wrote: "*El sol no si move*" (the sun does not move). These words and other observations contained in the same manuscript lead to think that Leonardo elaborated an early heliocentric theory several decades before Nicolaus Copernicus wrote the *De Revolutionibus* (Copernicus, 1543). Although Leonardo did not possess any scientific instrumentation able to plumb the depths of the skies and therefore prove his intuitions, he believed in the possible existence of a cosmological model in which the earth was not an immobile entity at the center of the universe.

Leonardo's intuition is of enormous importance and significance, especially if we consider the historical context in which it was formulated. The need not only to document and visualize Leonardo's vision, but also to convey the sharp contrast between the conception of a finite geocentric world and the vision of a heliocentric infinite space are the main reasons for the realization of the exhibit described in the paper.

## 3. VR TECHNOLOGY IN MUSEUMS

VR is a technology that allows users to explore and manipulate computer-generated, three dimensional, interactive environments in real time (Sherman, 2003). VR is based on the theory that people do not experience reality directly, they receive a series of external stimuli which are interpreted by the brain as reality. "If a computer application can send the same external stimuli that the brain can interpret, then the simulated reality is potentially undistinguishable from reality" (Akins, 1992). Two types of VR environments exist: desktop and total immersion. The installation described in the paper is an example of immersive, interactive VR environment. Immersive VR applications are usually presented on single or multiple,

room-size screens, or through a stereoscopic head-mounted display unit. The user interacts with the 3D environment with specialized equipment such as a data glove, a wand or a 3D mouse. Sensors on the head unit and/or data glove track the user's movements/gestures and provide feedback that is used to revise the display, thus enabling smooth, real time interactivity.

The use of immersive VR technology is a relatively recent trend originally limited to academic, military, and industrial research and development centers. Until recently, the high cost of VR displays and interaction devices coupled with difficulties in usability, operation and system maintenance have posed major barriers to the widespread use of the technology in schools and public spaces such as museums and cultural centers. Nevertheless, as the technology matures, VR applications are entering multidisciplinary areas such as education, art, history, and the humanities in general. Youngblut reports over forty VR-based learning applications (Youngblut, 1997) and Roussou describes about ten Virtual Environments designed for informal settings (Roussou, 2006).

As representative institutions involved in research and presentation of a variety of disciplines, museums are in an ideal position to make use of VR technology in order to "investigate its research, educational and entertainment potential while effectively shaping how it can be used to deliver education and recreation to the broad public" (Roussou, 2001).

To date, a few VR-based exhibitions have been produced in museums worldwide. The first exhibit that made use of VR technology is "The Virtual Ancient Egypt" installation funded by Intel's Design Education and Arts (IDEA) program. The application presented users with a virtual recreation of the Temple of Horus, constructed at Edfu during the New Kingdom era in ancient Egypt. It was exhibited in networked form at the Guggenheim Museum in New York and at the Machine Culture exhibit of SIGGRAPH '93 (Interacting with "Machine Culture", 1993).

Another early example is the "Virtual Endeavour" exhibit held at the Natural History Museum in London, UK in 1997. The installation included a 3D digital replica of Captain Cook's HM Bark Endeavour (The Natural History Museum, <http://www.nhm.ac.uk/>).

More recent applications are the immersive installations at the Foundation of the Hellenic World (FHW) in Greece (Roussou, 2000) (Gaitatzes, 2000). The VR exhibit "A Journey through Ancient Miletus" allows participants to walk or fly over an accurate 3D reconstruction of the city of Miletus, experience the life of its people, examine architectural details from different perspectives, and get an understanding of the sense of scale, proportion and space used by the ancient Greeks.

Another VR-based exhibition is the "Mayan Civilization" held at the National Science Museum in Tokyo in 2003 (Hirose, 2006). The exhibit included a VR theater with a 4mx14m curved screen onto which 3 Hi-Vision equivalent images were projected, and a large-capacity graphics workstation utilized for image generation. The exhibit propelled the visitors on an immersive voyage of discovery through a virtually synthesized Copan acropolis.

In addition to the fact that VR technology is becoming more affordable, VR exhibits are gaining popularity primarily because they offer three main advantages over traditional museum exhibits: (a) representational fidelity; (b) immediacy of control and high level of active user participation; and (c) presence (Hedberg, 1994).

(a) Representational fidelity refers to the degree of realism of the rendered 3D objects and the degree of realism provided by temporal changes to these objects. (b) User control and high level of participation refer to the ability to look at objects from different points of view, giving the impression of smooth movement through the environment, and the ability to pick up, examine and modify objects within the virtual world (Dalgarno, 2002). (c) The feeling of presence, or immersion, occurs as a consequence of realism of representation and high degree of user control. It makes the VR exhibit intrinsically motivating and engaging by giving the users the illusion of really being part of the reconstructed world, and by allowing them to focus entirely on the task at hand. In addition, several studies have shown that immersive VR applications can provide effective tools for learning in both formal and informal settings (Youngblut, 1997) (Roussou, 2007) (NCAC, 2003).

Because of this unique set of characteristics, we have focused on Virtual Reality as the technology of choice for the exhibit described in the paper.

#### 4. THE IMMERSIVE EXHIBIT

##### 4.1 The visual content

The visual content included 3D animated models of the geocentric and heliocentric systems. Both systems were modeled textured and animated in Maya 8.5 software (Autodesk Maya, <http://www.autodesk.com>). The Ptolemaic model consisted of eight polygonal spheres (the earth and seven planets), eight semi-transparent, concentric hemispheres, and a 3D avatar standing on top of the earth. The hemispheres represented the vaults enclosing the planets and the "sky of the fixed stars". The avatar's eyes defined the position of the point of view for the beginning of the virtual journey. Leonardo's universe included ten spheres (eight planets, the sun, and the moon) and one scaled-up hemisphere which symbolized the infinite galaxy. The Ptolemaic system is shown in figures 2-3; Leonardo's heliocentric model is shown in figure 5.

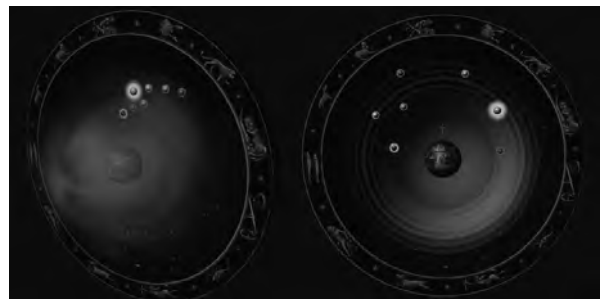


Figure 2: 3D renderings of Ptolemy's universe

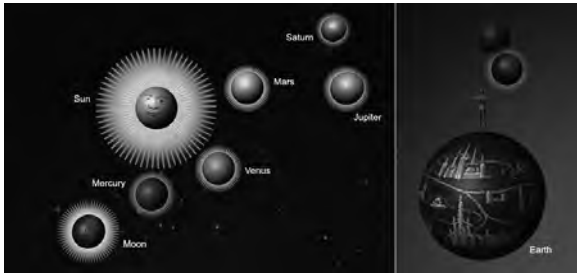


Figure 3: 3D renderings of close-up views of planets (left) and Earth with avatar (right), both from Ptolemy's universe



Figure 4: Reference images used to model Ptolemy's universe: illustrations from Andreas Cellarius *Harmonia Macrocosmica*, (left and middle), and from the Christian Aristotelian cosmos (right)

In order to maintain high speed of response in a real-time immersive environment, the polygon count of each model was kept fairly low (e.g. <30,000 polygons per universe). To realize high visual quality with a limited number of polygons, surface details were added by the use of a variety of colour, transparency and bump textures painted by the authors and applied to the surfaces as projection and parameterized maps. The textures of the Ptolemaic system were based on images from Andreas Cellarius *Harmonia Macrocosmica*, 1660/61 (Van Gent, 2003) and from the Christian Aristotelian cosmos, engraving from Peter Apian's *Cosmographia*, 1524 (Britannica online, <http://www.britannica.com/>). Three of the reference images are shown in figure 4. The textures of the planets in the heliocentric system were created in Maya Paint Effects with reference to NASA images (NASA, <http://pds.jpl.nasa.gov/planets/>), while the surface of the moon is based on Leonardo's "Notes and drawings relating to the Moon" and on "Studies of the Illumination of the Moon" (Leonardo da Vinci, Codex Hammer). A rendering of the 3D model of the moon and Leonardo's drawing are shown in figure 6.

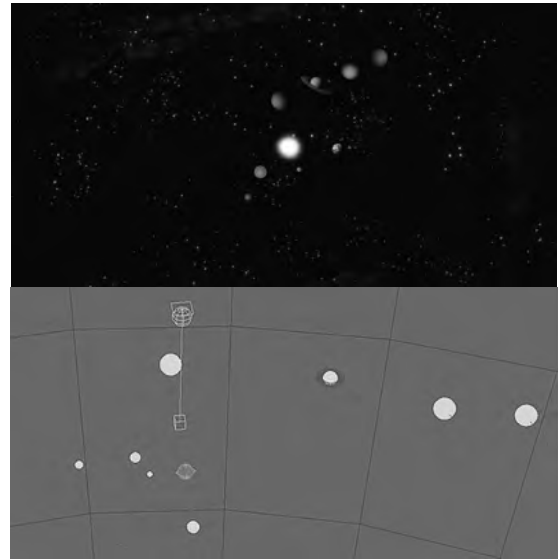


Figure 5: 3D rendering of Leonardo's heliocentric system (top); wireframe model showing the polygonal meshes and animation paths (bottom)

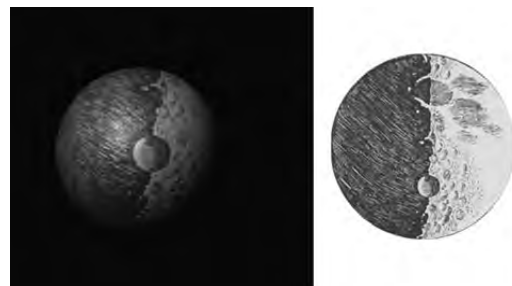


Figure 6: 3D rendering of Leonardo's moon (left), Leonardo's drawing of the moon (right)

The lighting setup of Ptolemy's model included two directional lights with 0.5 intensity; Leonardo's system was illuminated by one directional light with 0.4 intensity and one omni light (positioned in the center of the sun) with 1.0 intensity and glow effect. All planets were animated using motion path animation: the spheres were attached to circular paths in the geocentric system, and to elliptical curves in the heliocentric model. Camera motion was controlled in real time by the participant during the interactive journey.

The animated models were exported from Maya to VRML format and imported in Vizard 3.0 software (WorldViz, <http://www.worldviz.com/products/vizard/index.html>). Vizard is a 3D development interface that supports real-time rendering and interaction in the VR immersive environment as well as communication with the visualization display and tracking devices.

Images and videos of the models are available at: <http://www2.tech.purdue.edu/cgt/i3/da%20vinci/leonardo.htm>

#### 4.2 The immersive system

The VR system consisted of a screen and frame, a high-end laptop, two commodity projectors, a pair of polarizing filters, and passive polarized glasses. Despite the very limited size of

the room, the use of back projection allowed the audience to enjoy a usable space of 3x4x2.5m in front of the screen. Interaction was limited to navigation through the environments and was controlled remotely or by the participant. When controlled remotely, the user point of view was based on the position of the eyes of an imaginary viewer located approximately in the center of the group of visitors. Figure 7, left, shows a visitor travelling through the geocentric model.



Figure 7: Participant interacting with the exhibit (left); Torre della Rocca dei Conti Guidi (right). The arrow points to the location of the installation

#### 4.3 The architectural space

We chose to locate the VR exhibit in the “Hall of the Platonic Solids”, the highest room of the museum on the top floor of the “Tower of the Rocca dei Conti Guidi” (see figure 7, right). The choice of the spatial setting contributed to further emphasize the innovative and unique nature of the installation. Although the room is located in the heart of the museum itinerary, it is, at the same time, an independent and unique space with distinctive features that set it apart from the other museum rooms.

The room can be accessed through a steep staircase which immerses the visitors in a typical medieval setting, thus helping them assimilate the historical context in which Leonardo conceived his visionary ideas. The architectural space appears pure and essential, defined by the walls of the tower, on three sides, by the “sky of the wooden platonic solids”, and completely open on the entrance side. The environment has no predefined directionality and is designed as an “absent, invisible” space seamlessly and unobtrusively combined with the exhibit itself. No major changes to the room lighting conditions, temperature, and accessibility were implemented. Although just a first experimentation, the VR exhibit and the design of its spatial setting have allowed us to identify specific architectural and technical requirements (i.e. optimum spatial layout, lighting conditions, temperature, security, accessibility, maximum capacity) which will guide the design of a new museum environment for technology-based exhibits.

#### 4.4 The viewer’s experience

The purpose of the installation was to let the viewers visualize and experience Leonardo’s visionary concept of an infinite, heliocentric universe (anticipatory of the Copernican System) as opposed to Ptolemy’s model of a finite, geocentric world. The viewers were first immersed in the geocentric universe and taken through a virtual journey across the eight spheres of Ptolemy’s cosmological model. Then they travelled through Leonardo’s infinite universe and explored it from unique points

of view. The first journey allowed the visitors to experience the cosmos as a closed, static entity. The viewers navigated through a sequence of concentric hemispheric vaults (represented as semi-transparent shells) which enclosed perfectly spherical vitreous planets. The journey ended in the “vault of the fixed stars” visualized as a tangible, insurmountable edge. Representative frames of a visitor’s virtual journey through Ptolemy’s universe are included in figure 8.

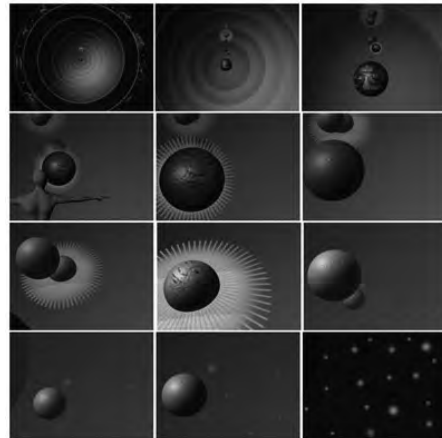


Figure 8: Frames extracted from the animation simulating a viewer’s virtual journey through Ptolemy’s universe

In the second journey the participants experienced Leonardo’s revolutionary concept of an open, dynamic universe part of an infinite time. The participant’s view could span freely in any direction across an open system of planets moving along elliptical orbits. The virtual journey never ended, as the space has no visible, reachable limits. The animation suggested a sense of spatial-temporal infinity which enshrouded the viewer throughout the duration of the voyage. Representative frames of a visitor’s journey through Leonardos’s universe, showing close-up views of the sun, planets and moon, are included in figure 9. We note that the frames in figure 9 show the point of view of the participant, therefore they do not represent the correct size of the sun and planets in relation to each other.

Overall, the visitors’ comments and reactions were very positive and enthusiastic. A selected group of participants (12) was asked to fill out a survey containing rating questions related to key aspects of the exhibition. More specifically, the subjects were asked to use a 5-point Likert scale (1=lowest score; 5=highest score) to rate the following features of the installation: usability, comfort, accessibility, spatial setting, visual quality, quality of interaction, degree of immersion, innovation, and overall quality of the experience. The mean rating values are reported in table 1.



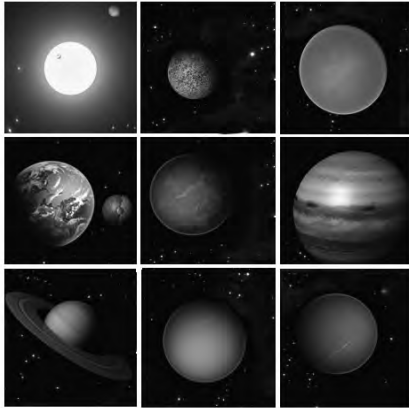


Figure 9: Close-up views of sun and planets extracted from the animation simulating a viewer's virtual journey through Leonardo's universe

Feature	Mean Ratings (1-5)
Usability	4
Comfort	4
Accessibility	4
Spatial setting	4
Visual quality of content	4
Quality of interaction	4
Degree of immersion	4
Innovation	5
Overall quality of the experience	5

Table 1. Survey results (mean rating values)

## 5. DISCUSSION AND CONCLUSION

In this paper we have described a VR exhibit developed for the Leonardo's museum in Vinci Italy. The purpose of the exhibit was to communicate the contrast between Leonardo's revolutionary concept of a heliocentric universe and Ptolemy's geocentric system. The setup of the installation consisted of a low-cost portable immersive system with head and hand tracking technology and passive stereo. The visual content included 3D animated reconstructions of the heliocentric and geocentric cosmological models projected onto a single flat screen. The viewer sat in front of the screen wearing a pair of passive polarized glasses and navigated through the environment using a 6DOF (degrees of freedom) wand or pinch glove.

Although the audience's reactions were very positive, the exhibition presented some weaknesses. For example, several visual details of the animated models created in Maya were not able to display correctly in the VR environment because of problems related to real-time rendering pipelines and file translation from the 3D software to the real-time environment. This loss resulted in a lower visual quality of the 3D content and therefore in a less engaging user experience. In addition, the installation did not provide a "fully immersive experience" because of limitations of the hardware system. According to Slater et al. (Slater, 1996) immersion is a quantifiable characteristic of a technology and is defined by the extent to which VR devices are *extensive, surrounding, inclusive, vivid and matching*. VR systems are considered extensive if "they

can accommodate many sensory systems"; they are surrounding if the information arrives at the participant's sensory organs from any (virtual) direction; and they are inclusive to the extent that all sensory data from reality is excluded. Vividness refers primarily to resolution and quality of the visual display, as well as richness of the information content, and matching refers to the correspondence between the "participant's proprioceptive feedback about body movements and the information generated on the displays". Although our installation met the requirements of vividness, matching, and, to a certain extent, inclusiveness, the system was not extensive, nor surrounding. It provided *visual* feedback only (sound and haptic feedback were not included), and the information content arrived at the user from only one direction (the screen).

Further, it can be argued that the major weakness of the exhibit was its limited interactivity. However, restricting the interaction to travel through the environments was the authors' choice, primarily determined by the purpose and content of the exhibit. The goal of the installation was not to let the viewers manipulate objects but to let them explore the two universes, observe objects from unique and diverse points of view, and directly experience the differences between the two cosmological models. We anticipate that the content of future VR exhibits will lead to development of more sophisticated interaction experiences which will require object selection, manipulation, and dynamic change of the virtual content.

Despite its limitations, the exhibit was very successful and the audience's reactions confirmed the effectiveness of VR technology as a visualization, research, education, dissemination and entertainment tool. This project can be considered a first case study which paves the way for the design of a novel museum space and for the establishment of a new technology infrastructure that will allow the introduction of VR exhibitions in the Leonardo's museum. The new museum environment will include a CAVE-like VR system with multiple screens and multi-sensory feedback, therefore many of the limitations listed above will be overcome.

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## THE DEVELOPMENT OF AN E-MUSEUM FOR CONTEMPORARY ARTS

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**KEY WORDS:** virtual museum, cultural informatics, e-Heritage, Web3D, laser scanning, educational games

### ABSTRACT:

The increasing development of interactive techniques and new information technologies' software and hardware and the decreasing of their costs have facilitated their use by a wide range of cultural institutions, such as museums. These new technologies also provided solutions for the lack of exhibition space, considerable exhibitions' costs and the fragility of some artifacts whose possible damage museum curators want to prevent. The value of these new tools and formats have been recognized and fruitfully exploited by curators for visualizing the cultural context of museum exhibitions. In addition, museums changed their way of conveying information about their cultural artifacts to the wide public, through new communication methods, like virtual museums, which have made the content and context of the museum collections more accessible and attractive to the wide public. During the last decade various kinds of 'virtual museums' have been developed either in the museums' environment, or over the World Wide Web. A virtual museum can be a digital collection that is presented either over the WWW, or to an intranet or even to a CD-ROM and it can be an extension of a physical museum, or it can exist only in a digital form. Furthermore, the virtual museum can have various forms. It can be a 3D reconstruction of the physical museum, where, in the virtual rooms of the museum exhibition, the visitors can navigate and explore its collections. Alternatively, it can be a completely imaginary environment, in form of various rooms, where the cultural artifacts are placed. This study describes all aspects of the creation of an e-museum for contemporary arts. Emerging tools, technologies, 3D digitization processes of museum spaces as well as artifacts are presented, public acceptance polls are discussed and educational scenarios are exercised. All presentations concern the actual case of the Macedonian Museum of Contemporary Arts in Thessaloniki, Greece.

## 1. INTRODUCTION

### 1.1 ICT and museums

Research work (Jones and Christal, 2002; Scali et al., 2002) and an extensive survey of the European museum sector (ORION Report) have shown that information technologies such as the World Wide Web (WWW) enhanced by three-dimensional 3D visualization tools can provide valuable help to achieve the aims mentioned above. Furthermore, the ever-increasing development of interactive techniques and of new information technology software and hardware accompanied by a decrease in cost resulted in their use becoming easier by a wide range of cultural institutions, such as museums. These forms of information technology are in effect empowering tools in the hands of the experts working at ensuring that the museums' goals materialise successfully. They provide solutions to issues of space limitation, of the considerable cost of exhibitions and of curator's concern with preventing any possible damage being incurred by fragile artifacts. The value of these new tools and formats has been recognized by curators who have effectively put them to use to ensure the visualization of the cultural context of museum exhibitions. Conferences such as the ICHIM Conferences on Hypermedia and Interactivity in Museums, which started in 1991 (available at: <http://www.archimuse.com/conferences/ichim.html>), and Museums and the Web established in 1997 (available at: <http://www.archimuse.com/conferences/mw.html>), highlight the importance of introducing new technologies in museums. The utility and the potential benefits of emerging technologies such

as Virtual Reality (VR) (Pletinckx et al., 2000; Roussou, 2001; Wojciechowski et al., 2004), Augmented Reality (AR) (Brogni et al., 1999; Liarokapis et al., 2004; Liarokapis and White, 2005) and Web technologies (Sinclair et al., 2003; White et al., 2004), for museums have been well documented by a number of researchers.

In the 1980s museums began to change the way they conveyed the information surrounding cultural artifacts to the wider public. There was a shift in the museology concept towards considering that the context and the information surrounding an item were more important than the item itself (Pearce, 1986; Washburn, 1984; McDonald and Alsford, 1991; Alsford 1991). By means of innovative methods and tools and through taking advantage of the potential of the WWW as a source of information for all, virtual museums were created. This has made the content and context of museum collections more accessible and appealing to the wider public and has enriched the whole museum experience. Over the last decade various kinds of virtual museums have been developed either within the actual museum environment, or over the World Wide Web. There is no official figure yet for the number of virtual museums presently existing worldwide but we know that there are thousands of them and that their number is rapidly on the increase (Information today, 2005).

A virtual museum is 'a collection of digitally recorded images, sound files, text documents and other data of historical, scientific, or cultural interest that are accessed through electronic media' (Encyclopaedia Britannica online). A virtual museum can be also called "electronic museum" or "e-

museum”, “digital museum”, “cybermuseum” or still “on-line museum” and “Web museum”.

With no standard definition prevailing for the term ‘virtual museum’, the definition adopted for the purpose of this article describes it as “(...) a logically related collection of digital objects composed in a variety of media, and, because of its capacity to provide connectedness and various points of access, it lends itself to transcending traditional methods of communicating and interacting with the visitors being flexible toward their needs and interests; it has no real place or space, its objects and the related information can be disseminated all over the world” (Schweibenz 1998).

According to ICOM (ICOM 2004) there are three categories of virtual museums on the Internet that are developed as extensions of physical museums: the brochure museum, the content museum and the learning museum. The brochure museum is a website that aims at informing future visitors about the museum. It usually contains administrative information about the museum, such as opening hours, services, types of collections, floor plan of the museum, map of the area where it is situated, contact details, etc. The content museum is a website created with the purpose of making information about the museum collections available. It can be identified to a database containing detailed information about the museum collections, with the content presented in an object-oriented way. The learning museum is a website which offers different points of access to its virtual visitors, depending on their age, background and knowledge. The information is presented in a context-oriented, rather than object-oriented, way. Moreover, the site is educationally enhanced and linked to additional information intended to motivate the virtual visitor to learn more about a subject of particular interest to them and to visit the site again. The goal of the learning museum is to make the virtual visitor come back and to make him/her establish a personal relationship with the online collection.

In the case of the virtual Macedonian Museum of Contemporary Art the last category of learning museum was selected. With the aid of emerging technologies, such as Web3D, and innovative approaches, such as educational games, a virtual environment that contains extensive information about the exhibits and their context, as well as additional research material, is under development.

## 1.2 Aim of study

The aim of the study is to present the tools and techniques used for the design and the creation of the virtual Macedonian Museum of Modern Art. The purpose of the virtual museum is to contribute to a complete and comprehensive presentation of the history and the exhibits of the Macedonian Museum of Contemporary Art. The presentation of the exhibits and their context will provide valuable help to the virtual visitors in understanding the museum exhibitions. The online navigation to the 3D space of the museum, as well as the presentation of virtual exhibits will invite the virtual visitors to participate in an enhanced museum experience and in museum meaning-making. Virtual games will also be added to the learning environment, in order to provide the opportunity for creative learning and entertainment at the same time.

## 2. STEPS UNDERTAKEN FOR THE CREATION OF THE E-MUSEUM OF CONTEMPORARY ARTS

### 2.1 Define potential virtual users

The design of the virtual Macedonian Museum of Contemporary Art is user-centred, it takes into account the user needs and it ensures the efficient and effective content, as well as the usability of the system by evaluation and feedback.

Its users are researchers and specialists of Contemporary Art, as well as students, or virtual tourists interested in art. They can have various backgrounds concerning their interests, knowledge, preferences, age etc. and it is considered important to satisfy the different profiles and characteristics. Thus, the potential users are interviewed and evaluate the system from its current early stage. For satisfying their needs the virtual Macedonian Museum of Contemporary Art will include information with various information depths in information layers.

### 2.2 Creation of virtual museum exhibitions

We used the most usual structure for virtual exhibitions that is defined by the structure of *exhibition spaces* (White et al., 2004). Each exhibition space may represent an entire exhibition, a part of the exhibition related to a particular subject, a museum gallery, etc. Subspaces may be used to divide exhibitions into smaller parts, e.g., focused on a particular topic. The exhibition spaces consist of two types of elements (ibid): the *Virtual Galleries* and the *Cultural Objects*. For their creation past research on/regarding the issues for consideration concerning the 3D representations was taken into account (Sylaiou and Patias, 2004).

The virtual exhibits are the principal means through which the virtual museum will communicate its mission objectives and they can be static or interactive. According to research the key features of an online interactive exhibit are: (a) multiplicity of contexts for the user to connect with the exhibit in a seamless manner, (b) good instructional design, (c) pro-active learning contexts, (d) good balance between learning and leisure, (e) no text-heavy pages to interfere with the learning experience (Tan Wee Hin et al., 2003).

Over the last decades there has been an effort to shift the focus from the aesthetic value of museum artifacts to their context as well as the historical information they encompass and the ideas they foster (e.g. Vergo, 1989; Pearce, 1992; Hooper-Greenhill, 2000). This changing perspective led museums to concentrate on telling stories about the objects, thus enabling visitors to construct semantic meaning around them. Historical narrative communicated establishes connectedness between the museum objects, visitors and various layers of information concerning their past context (Hoptman, 1992), and exposes cultural objects to new audiences around the world.

#### 2.2.1 Visualization of exhibition space

In our case the permanent collection was digitised by imaging technology and visualised by means of 360-degree Quicktime VR technology developed by Apple (Apple, Quicktime VR). It allows animation and provides dynamic and continuous 360° views. It has been preferred among others because it is a low-cost, but easy-to-use and efficient solution for enabling the

users to experience and interact with the permanent collection of the museum exhibition.

The space of the temporary collection was created by 3D Studio Max and visualised by Web3D technology. According to 2D digital drawings and accurate on-site measurements a 3D model of the temporary exhibition space was produced. Real textures from the building were used in order to produce a more photorealistic result. Internet technologies that have the tremendous potential of offering virtual visitors ubiquitous access via the WWW to the virtual museum environment. Additionally, the increased efficiency of Internet connections (i.e. ADSL) makes it possible to transmit significant media files relating to the artifacts of the virtual museum exhibition. Thus, virtual visitors can have access to the virtual Macedonian Museum of Contemporary Arts exhibitions via a PC and an Internet connection at any given time and from any given location. The most popular technology for the WWW visualisation includes Web3D which offers tools such as VRML and X3D, which can be used for the creation of a virtual museum environment that is much more interactive than many current museum web sites available, i.e. a catalogue of pictures and text in a web browser. The characteristic of Web3D systems is that they can transform human-computer interaction techniques and allow the creation of a new category of interactive applications that could very well act as the catalyst for launching the virtual museum revolution (Sylaiou et al., 2005). This new generation of tools can assist not only with the integration of museum archives into a reliable and low cost solution, but also with allowing remote access over the Internet.

The virtual museum is divided into two levels and each level consists of various rooms. Each room contains a number of exhibits. The layout of the virtual exhibition space can be seen in Figure 1.

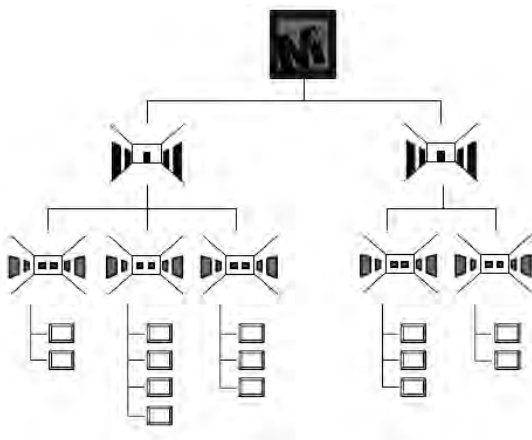


Figure 1: Virtual Macedonian Museum of Contemporary Art layout

### 2.2.2 Digitization of exhibits

The exhibits that were digitized for the creation of the e-museum of the Macedonian Museum of Contemporary Arts were of different sizes, shapes and materials. The digitization process was different depending on the complexity and the form of the exhibits. The exhibits were divided in two major groups two dimensional and three dimensional objects. Different

techniques were used for each group ranging from photogrammetry to laser scanning.

### 2.2.3 Digitization of 2D exhibits

For the digitization of the two dimensional objects of the MMCA traditional photogrammetric techniques were used. The exhibits were photographed using a high resolution 10 MP digital camera (Canon EOS 400D), with different lenses depending on the size of the object. Then the images were rectified using the projective transformation. The final images have a pixel size resolution of 0.5 mm. In figure 2 we can see the raw image (top) and the produced rectified one (bottom).



Figure 2: The initial image (top) and the rectified image (bottom)

### 2.2.4 Digitization of 3D objects

For the digitization of the 3 dimensional objects different techniques were employed depending on the complexity of the objects. For objects with low complexity, photogrammetric techniques were used. For their digitization an external orientation device was used and the data was processed using the Photomodeler software. The more complex objects were digitized using laser scanners. Depending on their size two different laser scanners were used. For large objects the Optech ILRIS 3D laser scanner was used, while for smaller objects the Minolta laser scanner was used. In figure 3 we can see an example of digitization for a small object of low complexity. The first two images are a subset of the initial images that were taken for the mapping of the object. We can see the external orientation device and the object from two different views. The external orientation device has 24 premarked control points measured with high accuracy. In the other two images we can see a partial model of the object that was created using the Photomodeler software.



Figure 3: Subset of initial photos (top), views of the reconstructed 3D model of an exhibit (bottom)

For more complex objects the laser scanners were used. Next we are going to show an example of a respectively large object. For the reconstruction of this model the Optech laser scanner was used, while the processing was done using the Polyworks software. Initially four scans from different angles were performed. The different scans were aligned using Polyworks Imalign. In figure 4 we can see the aligned model and digitizer positions. In figure 5 the different views of the object from each position. In order to facilitate the scanner the object was put in a revolving base and was rotated to acquire the scans. Finally the four scans were merged using Polyworks Immerge producing the final triangle model. Further processing to fill the model holes and clear the model was performed in Polyworks Imedit. The final model was rendered using photos from an external 10 MP camera (Nikon D80) exported in VRML format and inserted in 3D studio Max for further processing. In Figure 6 we can see different views of the photorealistic model.



Figure 4: Aligned 3D model and digitizer positions



Figure 5: The four different scan angles

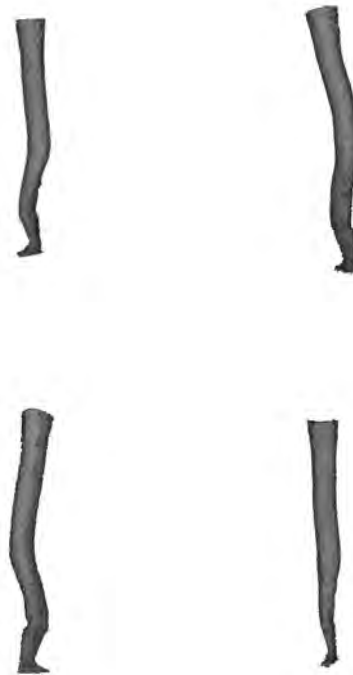


Figure 6: Captions of the final photorealistic 3D model

### 3. VIRTUAL MUSEUM FUNCTIONALITIES

#### 3.1 Navigation to the permanent museum exhibitions

The navigation to the permanent exhibition is created, as already mentioned, by means of Quicktime VR. More specifically, the virtual visitor will have the opportunity to look around the exhibition space.

#### 3.2 Navigation to the temporary museum exhibitions

Two options will be provided to the virtual visitors of the temporary museum exhibitions:

- i) Free navigation in which more experienced in these environments users will create their own navigation path, defining the direction, the objects, the speed and the time they will spend to each exhibit.

- ii) Navigation with the aid of map window choosing the place that s/he will visit by clicking on the 3D map with the exhibition spaces.

The navigation to the permanent and the temporary exhibitions will be real-time and they will have some space constraints to prevent the virtual navigator from reaching a deadlock and to avoid the sense of disorientation.

### 3.3 Examination of the exhibits

The QTVR and panoramas files are connected with other files containing information about the exhibition space and the exhibits will be added by hotspots. The visitor can click on the exhibit and open a window with a scalable image that allows panning and high-quality zooming and provides the desired level of detail and information about it (e.g. text about the artefact, the artist, bibliography, sound).

The 3D exhibits can be examined from various points of view by rotation. Information about them can be extracted by clicking on them and opening a window with information concerning their context.

### 3.4 'My Gallery'

My Gallery is a functionality of the virtual museum that provides the opportunity to the virtual visitor to become a "curator" and to create its own exhibition in an empty 3D space. By the Search option the virtual visitor can search for exhibits by keyword concerning the title of the virtual artefact, the artist, the material that is created etc. The results of her/his search are visualised as thumbnails from which it can choose and "drag and drop" the exhibits to its own virtual exhibition space. Furthermore, s/he can take snapshots and send them by e-mail to friends, or save them to her/his PC in order to keep the information about the exhibition that created.

These functionalities are both entertaining and educational. They can provide aesthetic satisfaction and contribute to creativity, but at the same time, they can be a valuable tool in the hands of architects and museologists and students of these Departments for experimenting and evaluating ideas about exhibition approaches.

### 3.5 Educational games

After the navigation to the 3D exhibition space the virtual visitor will have the opportunity to play some games in order to test the educational effectiveness and measure the impact of the virtual exhibition to its visitors.

#### 3.5.1 Quiz

An educational quiz is provided by choice to the virtual visitor with multiple choice questions about the exhibits of the virtual exhibition. The correct answers will provide points and the high scores will be followed by bonus and awards connected to the exhibits of the museum, in order to increase the motivation of the visitors.

#### 3.5.2 Hidden treasure

The hidden treasure is a game in which the virtual visitor searches for an exhibit with specific characteristics (e.g. an exhibit made by papier mâché). The virtual visitor will be

driven by instructions and s/he will watch the path chosen and position to a ground plan. The game will have various levels of difficulty and it will also have a "point system" connected to awards.

## 4. NEED FOR EVALUATION

In order to test the efficiency of the virtual Macedonian Museum of Contemporary Art, it shall be evaluated under real circumstances, not only by a demonstration of its capacities, but also through the contribution of real end-users, so the necessary system improvements will be made. It will be based on interactive and user-friendly interfaces that meet current end-users' demands and contribute to their education and entertainment.

Its usability will be assessed with the aid of the usability evaluation guidelines: learnability, efficiency, memorability, errors and satisfaction developed by J. Nielsen and his colleagues (Nielsen 1994). Heuristic evaluation and cognitive walkthroughs will be used. Heuristic evaluation guidelines (Nielsen 1994) were used to evaluate the user interface of the system inviting human observers. According to these guidelines, a system must provide feedback and visibility of the system status employing simple language with clearly marked exits. Consistency of user interface elements is required and user's memory load must be minimised. The user interface shall have aesthetic and minimalist design and it has to be able to deal with errors. Finally, help and the appropriate documentation should be available. Cognitive walk-through methods (Nielsen 1994) involve the 'walk-through' of a number of tasks, exploring the systems' characteristics, locating and identifying potential problems and their causes.

A mixed-methods evaluation approach combining quantitative and qualitative research methods will be adopted (Sylaiou et al., 2004; Sylaiou et al., 2008). In the evaluation not only simple users, but also experts will participate. The methodology undertaken will also involve experts that will evaluate the virtual museum. More specifically the virtual museum will be evaluated by:

- the domain experts, the curators that do have no direct knowledge of technological usability evaluations,
- the usability experts, who were aware of the usability aspects, that will act as visitors of the virtual museum (Karoulis et al., 2006a),
- the end-users (Karoulis et al., 2006b).

## 5. CONCLUSIONS AND FUTURE WORK

In this paper the first steps undertaken for the creation of the virtual Macedonian Museum of Contemporary Art are presented. The methods, tools and techniques that will be used are discussed. The virtual Macedonian Museum of Contemporary Art has the potential to both preserve and disseminate the cultural information in an effectively and low-cost method through innovative methods and tools. It will be an engaging medium with great appeal to a variety of groups of visitors and can promote the 'real site' by providing information about museum exhibitions and offer an enhanced display of museum artifacts through emerging technologies. The visit to the virtual museum will be an enjoyable and productive experience that draws the user into involvement and participation and help the promotion of the real museum (Jackson et al., 1998). The virtual Macedonian Museum of

Contemporary Art can be a ubiquitous place for expression, where users can become creators as well as consumers of information (Frost, 2002).

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## A WEB-BASED VIRTUAL MUSEUM APPLICATION

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**KEY WORDS:** Virtual Museum Applications (e-Museums and e-Exhibitions), Virtual Tour, Internet-based Cultural Heritage Applications, Spherical Panoramas, High Dynamic Range Imaging.

### ABSTRACT:

A virtual-tour allows users to explore places of cultural interest such as museums or archaeological sites. This makes exhibits available to a broader audience that might not be able to travel physically, or serves as an incentive to visit the real place. The widespread use of immersive environments is a desirable goal for cultural heritage, and there are already many websites offering increasingly sophisticated visualisations. We have created a virtual museum web-application composed of connected spherical panoramas by using affordable hardware and software. To preserve a perceptually accurate visualisation of the museum's collections, within the context in which they are presented, the main focus of our work is to create high quality spherical panoramas with realistic colour and tone reproduction. We achieve our goal to create a virtual tour by connecting spherical panoramas created using commonly available photo stitching software, combined with methods like geometric correction, high dynamic range imaging (HDR) and tonemapping where applicable.

## 1. INTRODUCTION

### 1.1 General Background

Virtual tours based on panoramas offer a more immersive impression of a place than it is possible with classical photographs. This helps to further open places of cultural or historic interest to a broader audience that might not be able to travel physically or serves as an incentive to visit the real place. This is one reason why this technique is used by many projects in tourism and cultural heritage around the world. Examples are

the World-Heritage-Tour (Dupret and Chen), Panoramas.dk (Nyberg) or the Virtual Tour of Oxford (Harrison). Here, we present a project which has been carried out in collaboration with the Byzantine Museum and Art Galleries in Nicosia, Cyprus. Their collection includes many rare exhibits such as mosaics and icons which have been created throughout the Byzantine period in Cyprus and which are some of the only remaining examples of their kind. Our goal is to give a web-visitor the opportunity to browse through the exhibits of the museum and to offer both a closer look to the artwork as well as related additional information.



Figure 1: Screenshot showing the web-application with superimposed additional information and a floor-plan as a navigational aid.

## 1.2 Spherical imaging techniques

There exist many techniques to create spherical panoramas (Jacobs, 2004; Reinhard, 2005). In the following, we present a brief overview of the most common techniques. One approach is to take a picture of a highly reflective sphere. Due to its geometric properties, a sphere reflects almost the whole of its surrounding environment into the lens of the camera. This allows the creation of a full spherical panorama with as little as two photographs taken from different angles. However, due to the distortion of the sphere, the spatial resolution of the final panorama is limited compared to other methods. A further way of capturing spherical panoramas is to use a SpheroCam camera (Spheron VR AG). These devices are line-scanning cameras that, while rotating, capture column after column of the spherical panorama. Although these cameras are able to produce high quality image files they are expensive and therefore not readily available for small cultural heritage projects. The most common approach today is to capture multiple images in a circular pattern and to use a computer to stitch them together afterwards. Depending on the focal length of the lens, the final resolution of the panorama can, according to requirement, easily be varied. Due to advances in stitching algorithms, this affordable method delivers very accurate results, provided data capture is carried out thoroughly. In principle, it is possible to use any camera to capture the slices of the panorama. However, digital SLR-cameras usually have a much larger sensor than compact models which results in a better signal to noise ratio as well as allowing more control in post processing by capturing images in RAW mode.

## 2. CREATING THE SPHERICAL PANORAMAS

### 2.1 Preparation of data capture

The virtual tour of the museum covers multiple rooms over three floors as well as some outdoor scenes. To make sure that the viewing angle towards the exhibits of the museum is not too steep, we planned the location for each sphere of the virtual tour to be able to later interconnect them in a plausible way. Using a floor-plan of the museum, we were able to rule out occluded areas and inconvenient vantage points. Consequently our application allows visitors to conveniently jump from scene to scene, or to zoom into the artwork without too much visual distortion.

### 2.2 Data capture

To preserve the impression of the artworks and the surrounding context within which they are presented, our main focus was to create high quality spherical panoramas with realistic colour and tone reproduction. We used a Canon EOS 5D with a 17mm wide-angle lens as our capture device. The 12 megapixel full-frame sensor of this camera model delivers both a high resolution as well as a good signal to noise ration due to relatively large photo sites on the sensor. To be able to accurately rotate the camera around the nodal point of the lens, we used a Manfrotto 303SPH panorama head mounted on a tripod (Figure 2). Furthermore a cable shutter release was used to both reduce vibrations caused by the shutter release, and make the image capture more convenient when rotating the panorama head. It is very important to carefully prepare the camera set up as mistakes can make the assembling process of the images more difficult or even impossible afterwards. To avoid parallax errors between individual shots, it is essential,

rotate the camera exactly around the nodal point of the lens (Jacobs, 2004; Frich, 2007). Furthermore, white balancing, aperture and ISO settings have to be fixed assuring that there are no unintended colour shifts between the single shots forming the panoramas afterwards.



Figure 2: The camera mounted on a tripod with attached panorama-head.

Bright light sources, daylight coming through windows and intense contrasts in the scene are generally challenging in photography. Therefore to compensate for extreme under- or overexposure, we used High Dynamic Range imaging techniques (HDR) for data capture (Reinhard, 2006; Bloch, 2007) where appropriate. An HDR image is created by combining a set of photographs taken with a range of exposures allowing us to compensate for extreme overexposure in light sources or to balance out unevenly lit areas. Figure 3 shows a fresco which has been digitally post-processed and blended to give a better appearance in the dark areas as some elements of the original scene were too dark compared to the overall scene.



Figure 3: By using HDR techniques and blending the lightness of unevenly lit areas like the fresco above the altar can be easily balanced out.

### 2.3 Assembling the panoramas

The geometric alignment of the individual images is challenging. Even with an accurately set nodal point and modern stitching algorithms offering distortion correction, there are often ghosting artefacts visible in the resulting panoramas. Applying a geometric correction to the camera files can solve this problem as even professional lenses show some geometric error like distortion or chromatic aberration. There are many tools available to compensate for this errors, like the Adobe Photoshop filter 'Lens Correction', DxO or PanoTools. We used LensFixCI (Kekus Digital) as it is reasonably priced and based on PanoTools (Dersch) which uses a lens database to correct for geometry errors.

To use the HDR photographs in a standard web environment, they had to be tonemapped. This is a process of compressing the tonal range of the HDR image, which usually shows a higher luminance range than a normal computer monitor or TV is able to display (Reinhard, 2006; Bloch, 2007). To maintain the human perception of self-luminosity of light sources (Zavagno, 2005), we allowed some clipping of high luminance features. Figure 4 shows a chandelier where this method has been applied.



Figure 4: Partial clipping in the chandelier to maintain the perception of self-luminosity of light sources.

We then spatially blended these HDR-images together with low dynamic range images (LDR) of parts of the panorama that only show a moderate contrast. This leads to spherical panoramas representing more of the classic photographic look most people are accustomed to but with more detail in the light and dark areas, and avoiding hue and saturation shifts as well as distracting halo-effects common with locally tonemapped HDR images (Reinhard, 2006). Finally, Autodesk (formerly Realviz) Stitcher was used to assemble the final panoramas. The auto-stitching mode of this software allows a relatively fast way to create spherical panoramas from the corrected image files.

### 3. THE VIRTUAL TOUR

The final virtual-tour has been created by using the SPi-V web-engine, which offers a hardware accelerated display of the tour inside the web browser. In order to connect the individual spheres, we created XML files using SPi-V's XML tag syntax to reference the panoramic images forming the virtual tour.

Inside the tour, interactive buttons allow jumping between individual scenes or provide more detailed information about the exhibits. For easy orientation, a floor plan of the museum has been included which can be toggled on or off in the toolbar at the bottom of the page. This map allows a convenient way of switching between floors or to navigate to a point of interest using hotspots placed on each floor, while at the same time showing the user's current location and orientation in the museum (Figure 1).

### 4. DISCUSSION AND CONCLUSION

The whole project could be carried out smoothly due to careful preparation before and during the data capture process. In total, we created 43 spherical panoramas, each with a final resolution of 10,000 by 5000 pixels for their equirectangular projections with a web compatible colour depth of 8 Bits per channel. At present we have implemented an internet-based virtual-museum application that allows visitors to freely browse the museum

examining specific collections they are interested in. As usual for spherical panoramas, it is possible to freely pan and to zoom in or out, allowing visitors to have a closer look at interesting elements in the scene. This is supplemented by additional information, where it is available for specific pieces. A floor-plan of the museum showing the available panoramas connects the virtual-tour together into an easily navigable structure. A possible future application for the already created spherical panoramas is a kiosk-like terminal, allowing tourists to still view collections if the museum or a part of it is closed.

Overall the use of spherical panoramas is relatively widespread on the internet because stitching methods, such as the one used in our work, allow a convenient and affordable way to create them. When connected as a virtual tour, they allow experiencing cultural heritage sites in a more immersive way than ordinary photographs. This combined with our use of HDR imaging methods for accurate colour and tone reproduction provides for an effective visitor experience. The final virtual walkthrough can be accessed at the following address: [www.makariosfoundation.org.cy/byzantine\\_spi/dswmedia](http://www.makariosfoundation.org.cy/byzantine_spi/dswmedia).

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## REMOTE VIRTUAL ACCESS TO 3D PHOTOGRAMMETRY: e-VMV VIRTUAL MUSEUM OF THE VILLA REALE IN MONZA

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**KEY WORDS:** multiuser, photogrammetry, virtual museum, 3D reconstruction

### ABSTRACT:

The task of describing something that already exists was always considered to be a major challenge because of the important role of the fourth dimension of time that is a strong component of any historic, archaeological or architectural entity. The continuous metamorphose, whether it is a material or a spatial change, makes us unable to describe fully any study case considered, but the advanced surveying techniques and continuous methodology development allow us to obtain and manage highly faithful models of the reality. The experience that this paper will describe has provided the opportunity to develop different techniques of model construction in CAD environments and three-dimensional vector graphics and animation software, using both range and image based input data, successively texturized using photogrammetric products such as rectified images and orthophotos. This paper will hence illustrate the different methodologies applied to the monument of Villa Reale in Monza using both photogrammetric and laser scanner survey in order to achieve the construction of detailed models to be used for the heritage digitalization and most importantly to provide the possibility of interaction at different spatial and time distances. The objectives: on one side, are improving remote access of 3D data that will allow in the future to support advanced programs of conserved maintenance of the architectural heritage in case of mixed use (public-private), in order to guarantee a sustainable intervention and the maintenance in the time; on the other hand, to support easy knowledge diffusion to a wide citizen users through a web vehicle, sharing survey for the sampled thematic axes. These are the strategic aims of the research project carried out within the General Direction of Lombardy Region (owner of the Villa).

### 1. PHOTOGRAMMETRIC DATA ACQUISITION AND ORGANIZATION WITHIN A WEB PORTAL

#### 1.1 From raw range and image based data to 3D modelling

At the present state, the pathway of the digitalization of the cultural heritage begins with data acquisition and ends with an interactive virtual 3D model on a computer. The task of describing something that already exists was always considered to be a major challenge because of the important role of the fourth dimension of time that is a strong component of any historic, archaeological or architectural entity. The continuous metamorphose, whether it is a material or a spatial change, makes us unable to describe fully any study case considered, but the advanced surveying techniques and continuous methodology development allow us to obtain and to successively manage extremely faithful models of the reality. Currently, the laser scanner point clouds are commonly used as the starting data for many types of surveys while photogrammetry remains the most complete technique for the metric and rigorous texturisation of 3D models. This approach is assumed because for the complex architectonical and archaeological items the surface reconstruction from the point cloud is not enough and moreover, it does not allow a realistic model visualisation. In the field of survey disciplines the definition of a model is always subjected to the purpose of the survey because every architectonical organism is in a constant, dynamic change. Therefore its model can only be partial representation of some, previously defined aspects maintaining, however, a high level of detail and definition.

The most recent technologies allow a construction three-dimensional models that can contain high level of geometric detail but to build very accurate and realistic, measurable models, they need to be texturized with high precision photogrammetric products – rectified images and orthophotos. While rectified images are mainly used for the so-called bi-dimensional objects (such as walls and pavements), orthophotos must be employed for the representation of so-called three-dimensional elements (such as vaults or apses in architecture, elements with a distinct third dimension).

Since the texturisation process requires a high-definition DEM/DSM (Digital Elevation Model/Digital Surface Model) to be defined, a solid model was built using laser-scanner data. (Figure 1 and Figure 2) The raw data obtained using this technology (cloud points) and are difficult to use since very “heavy” (ex. a file .imp of a single room of Villa Reale in Monza contained up to 180-200 MB of information). Therefore, it is necessary to filter and decimate the laser data in order to build a *mesh*, a 3D surface, that will serve as a Digital Model for the texturization. A solid model is also preferred because it can be used within more types of software, both photogrammetric ones and the ones used for modelling.

Once that both, the solid model and digitalized images, are in the same reference system and that the parameters internal and external orientation are known, the corresponding image coordinates are calculated for every vertex that constitutes the 3D surface while RGB values within the projected triangle are assigned to the surface (Remondino F. et al., 2006).

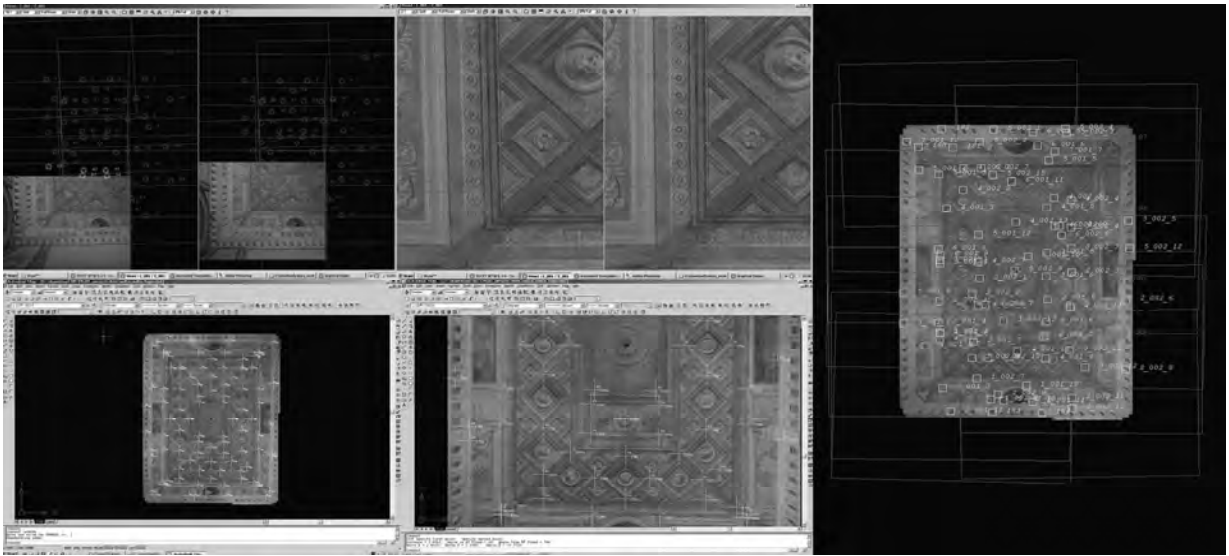


Figure 1 : Above, clockwise from left up: photogrammetric block of 14 photogramms with a rectified and non rectified image; rectified and non rectified image, close-up; orthophoto with frames of all images used, the GPs and TPs; orthophoto inserted in Cad and overlapped with topographic points, close-up and a distance measurement; orthophoto inserted in Cad and overlapped with topographic points

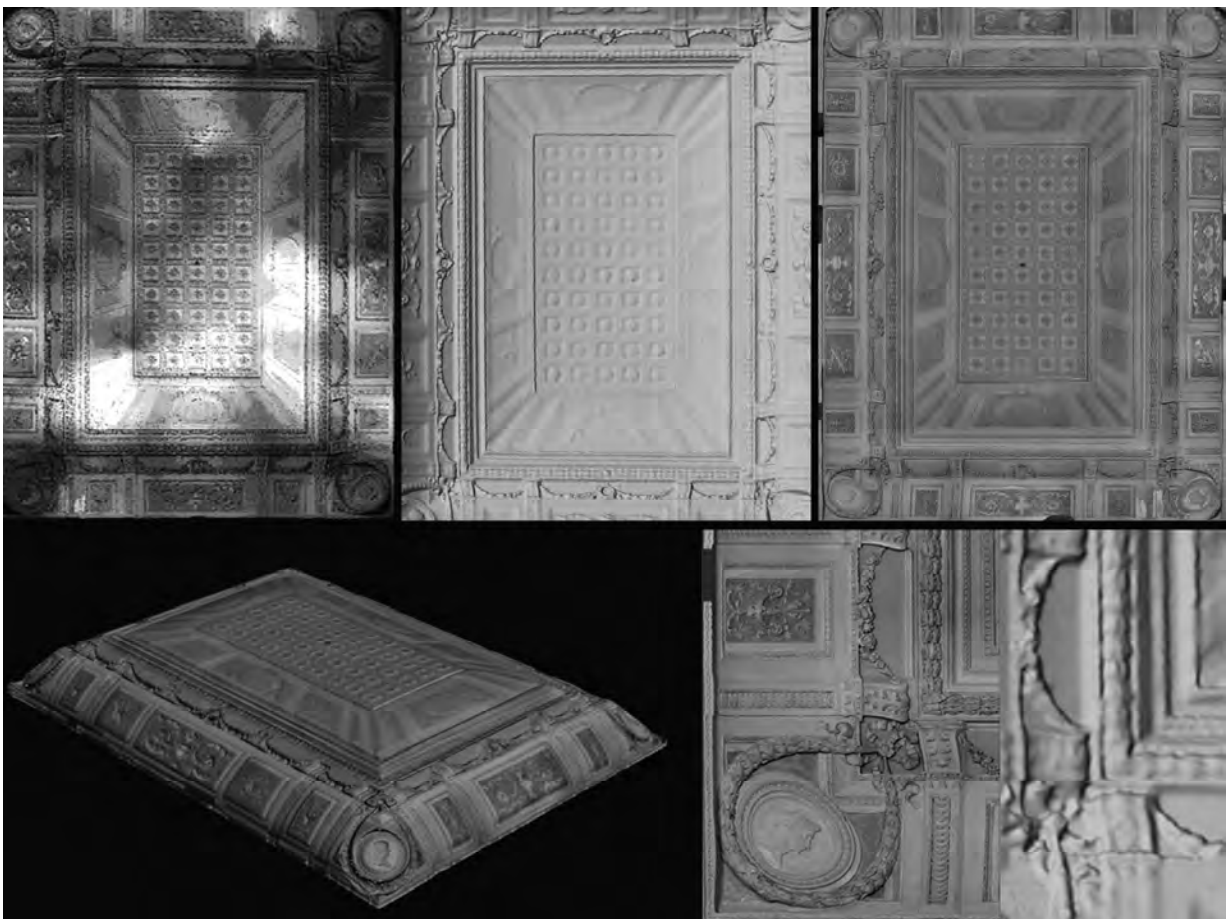


Figure 2 : Above left, clockwise: Sala della pendola (The room with a pendulum clock) vault – cloud point, solid model and orthophoto; a close –up on a solid model; a close-up on orthophoto; textured model of the vault

In this way an orthophoto acquires all of its three-dimensional properties and operations such as surface and volume measurement are not anymore approximated but can be realistically carried out in space, in environments similar to the ones of virtual reality.

## 1.2 Organisation of survey material within a web portal and innovative tools developed

The enormous quantity of data acquired and elaborated was successively organized in a *box diagram* where every room was treated as an open box and “broken down” into single elements (walls, pavements and vaults) represented with geometric drawings, rectified images and orthophotos. All of these elaborated data served for the construction of 3D models built in Cad environment, implemented with detail and texturized in 3ds Max, one of the commercial software that has a strong anti-aliasing potential within the rendering process.

To facilitate and make more interesting the data consultation and comparison, some of the newest utilities and plug-ins have also been employed. A tool *Zoomify* was used in order to view in high detail (scale 1:1) every single element of a room in a pop-up window, while an internally developed code allows to consult two windows simultaneously (Figure 3). In this way, for example, two historic maps of different periods or a historic map and recent one, could be navigated contemporarily, an operation that allows a immediate data comparison. A plug-in called Autodesk Design Review allows AutoCad drawings, in this case the geometric survey of the whole compound, to be viewed by all types of users or to be downloaded or directly measured on-line by a professional users.

## 2. E-VMV.WEBPORTAL OF VILLA REALE IN MONZA: WORK IN PROGRESS

### 2.1 Reorganization

The virtual site e-VmV\* (Figure 4) has been developed, during the prototyping phase, with Flash technology in order to obtain rapidly a feasible graphic results to support the function requested and to evaluate possible future evolutions.

Passing from a prototype level to a web site accessible by everyone through an easy service distribution of spatially referred information, the implementation of the e-VmV referring to the modern standard web has been scheduled in order to guarantee the e-content access to the most wide navigation platform set supported by PC, Palm cell phone, tvbox. The first step is the transferring and traducing of the site content on xhtml format.

Here follows the programme explanation on the publishing of the web site e-VmV within the next 6 months, regarding different points of view and expected aims. This operation will allow a better and more simplified indexing of the site content by the search engines.

### W3C for the document validation (CSS standard)

The aim is to align the site to the guide line defined by the W3C (World Wide Web Consortium <http://www.w3c.org>) for validated document generating “XHTML 1.1”.

The web document style will be implemented through “Cascading Style Sheet”, validating the pages along the CSS standard as defined by W3C.

Regarding the indexing process from the search engine there has been predicted a creation of an index in the Site Map, defined by Google, in order to allow a smart scan of the contents so as to distribute the most updated research results.

### Usability of the web site by people with handicap (WAI)

A particular attention to the e-VmV developing will be given to strategies, guidelines and resources, according to the Web Accessibility Initiative guidelines, to make accessible the site contents to the persons with handicap. (WAI <http://www.w3.org/WAI/>) The e-VmV is expected to be reordered and aligned most faithfully to these specifications.

### Structural approach of a tree-tier architecture

The structure must be reorganized so as to distinguish the data presentation from the contents and from the logic management to facilitate the updating and maintenance of the web site. Regarding the structural aspects a reorganizing along a tree-tier architecture is expected, with the interface represented by a web server and possible static contents, the business logic to be created through languages for the dynamic contents generating and with persisting data managed by an RDBMS

### Improving Video contents usability

In order to allow a more simple usability of video content, a “streaming on demand” server will activated to permit the user access to videos without pre-process of downloading on the local pc.

Once catalogued all the contents within a GEOdbase, there will be created a user interface thorough which querying the system will be possible. Content Management System is scheduled to support the updating of documents and information available on site, the users administration and to grant the privileged licences.

## 3. NEW ASPECTS OF IMAGE BASED MODELLING

### 3.1 Navigation and interaction with measurable models

One of the main tasks of the webportal prototype done for Villa Reale in Monza was to provide a virtual space for different virtual tours and 3D interactive navigation of the whole complex surveyed and for various types of users, starting from the three-dimensional wireframe models successively texturized. In fact, the definition of different users categories had also defined different types of models (with different level of detail or other information) to be used and also different levels of interaction allowed to the user (comparable to a behaviour standards in virtual realities). Therefore two types of products were done for all rooms: one that is a video that combines the illustration of the model and the processes of its construction with also some historic scenes found in bibliography and another one that is

\* requested by Regione Lombardia – Direzione Generale Culture, Identità e Autonomie della Lombardia (General Direction of Culture, Identity and Autonomies of Lombardy region)

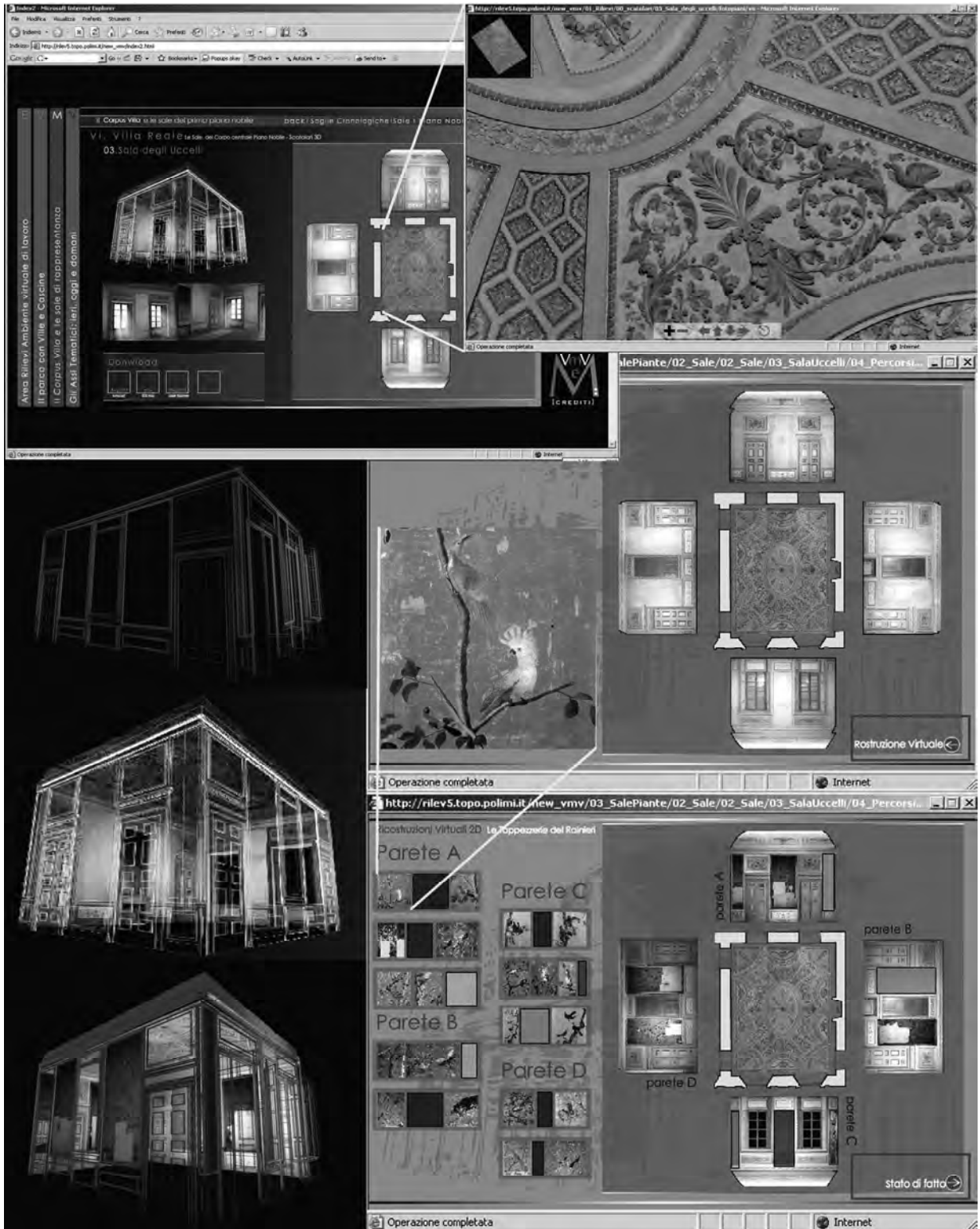


Figure 3 : Above left, clockwise: a webpage with a single room representation (*Sala degli uccelli* – The room of the birds) and the close-up on the vault (the pop-up page with a zoom up to scale 1:1; the webpage of the room at state of art; the webpage of the room with 2D reconstruction of antique tapestries with details on the left; detail pop –up page, done for all tapestries. 3D model – wireframe, wireframe with photogrammetry texturization, model with antique tapestries inserted ( at the moment not present and conserved in depository of the Villa Reale)



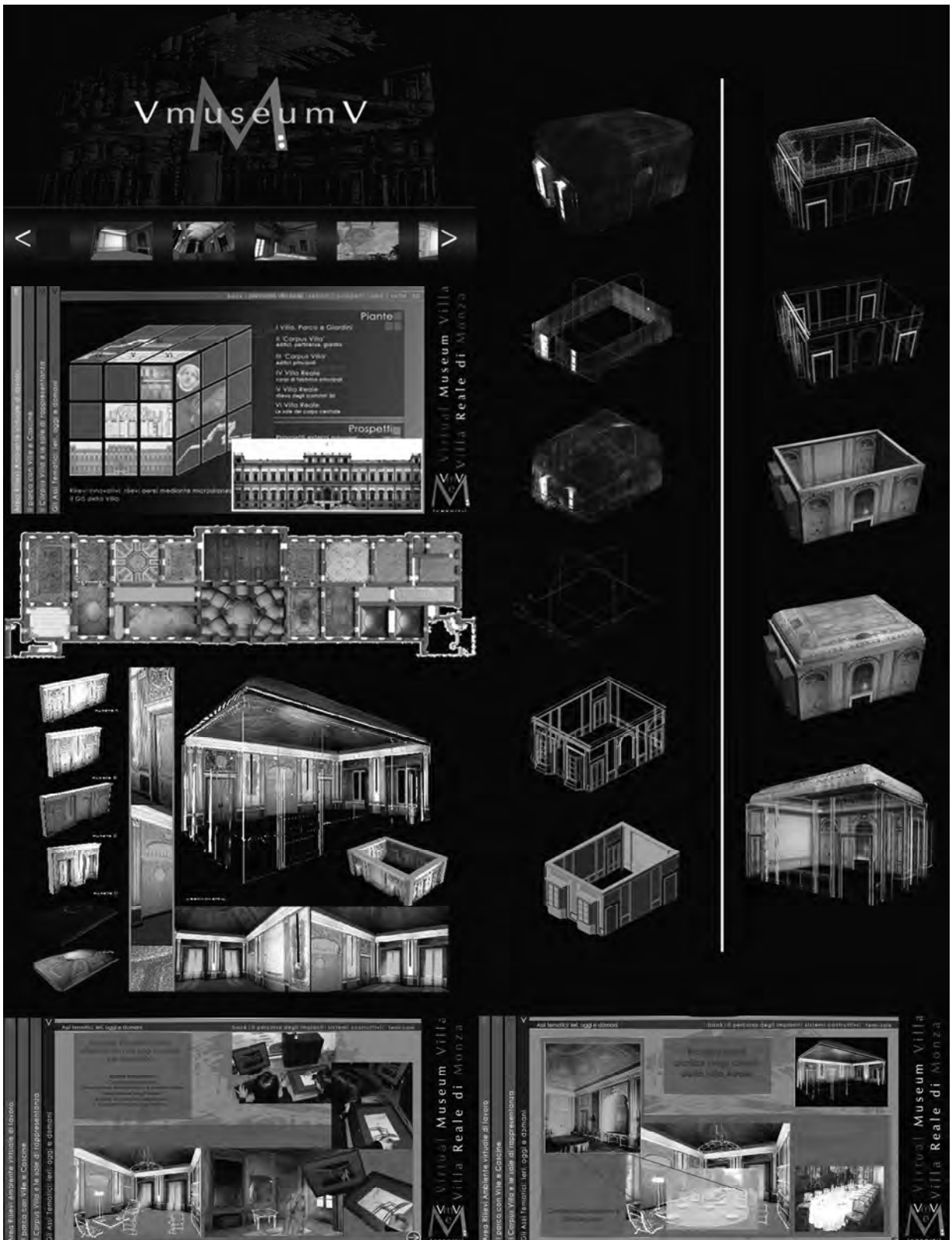


Figure 4 : From left up, clockwise: the main webpage window from which the visit to a single room can be chosen; the process of model construction from a laser scanner cloud with photogrammetric texturization; webpage of the historic scene reconstruction of some rooms; webpage of the future arrangements for potential exhibitions; the cube menu that contains the survey of the whole *da pranzo di famiglia* (The family dinning room)

VRML solid model that enables the navigation and a 3D interaction by the user. These products are actually both, the result of the concept that leads towards the conservation and the programmed maintenance of Cultural Heritage today and a proposal for the future approach for its the digitalization and usage. Providing a virtual space where different types of users (whether it is a 'home' user, or the 'professional' user such as, historians, architects or other researches) can meet and interact, means being able to provide a system of data that are easily consultable and most importantly up-datable (one of the aspect that is currently developed on our portal) giving, therefore, the possibility of interaction even at different spatial and time distances.

### 3.2 Complex forms: usage of non – conventional photogrammetric asset in Close Range Photogrammetry

The worldwide experience in close-range photogrammetry has encountered numerous problems using the traditional shot acquisition, vertical towards the object of survey, i.e. an asset requested by traditional software. This approach requires that the z-axis (objects third dimension) is always 'incoming' towards the camera, thus all the reference systems (GCPs or cloud points) have to be roto-traslated in order to be compatible with the photogrammetric one. Also, in close range photogrammetry the most convenient asset is almost never the vertical one because it often creates "shadows" i.e. hidden parts on the survey object (for example, for archaeological and architectural entities that are complex and difficult to reach and usually richly decorated objects (Figure 5). Nowadays, however, new software\* have been developed in order to facilitate the photogrammetric survey of object using oblique convergent images. In this way the object can be surveyed from any point of view, respecting the laws of stereoscopy and with no need of a particular reference system for the images.

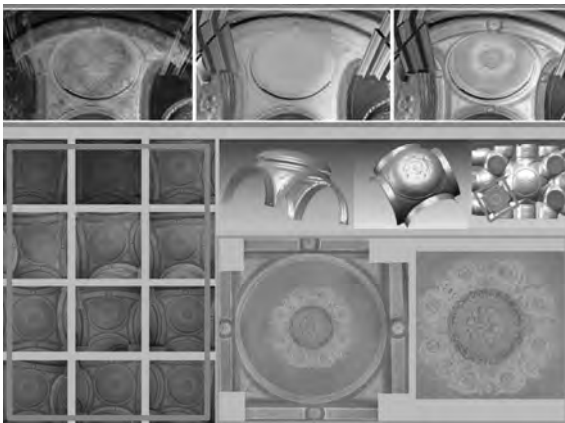


Figure 5 : Above: an example of the vault of Atrio della Villa Reale in Monza (Entrance Hall of the Royal Villa) – a point cloud model of the vault, a solid model, an orthophoto projected on a solid model. Below, clockwise: an experiment using multiple oblique shots processed in PhotoModeler - a block of 12 photogramms used to create an orthophoto, 3D surface obtained from laser scanner data, an overview of the vault's solid model; an orthophoto with a detail

\* Software based on this kind of philosophy are nowadays Photomodeler, Iwitness while inside Elab3DPOLI a software of this kind (MiMO) is also being developed

### 3.3 Virtualisation of historical scenarios

This aspect is of a particular interest among the historically important monuments that at a certain point, in part or completely, cannot be visited. Their reconstruction is of a fundamental importance for the Cultural Heritage community not only because it allows visitors to view its general information but because it could provide a realistic interaction and navigation within the 3D models (Figure 6).

Currently, another feature has been developed within the Elab3DPOLI of Politecnico di Milano – that of virtual scene reconstruction of historic images. In this case, the homologous points of the digitalized historic image have been "recognized" on a spatial model and the image has been re-projected thus gaining three-dimensional properties otherwise not intrinsic of a photography, which is in fact a simple prospective image. Moreover, the historic image is in that way georeferenced and contains the parameters that allow for it to be inserted in an already existing model and analysed in other work environments (ex. 3ds Max). Extraordinary results obtained in this way can be extremely valuable for the historic and architectural analysis of sceneries that no longer exist but fortunately their photographic documentation does and could enable the construction of three-dimensional spatial models easy to navigate, to measure and to interact with (Figure 7).

## 4. RESEARCH FOCUS: EXPECTED FUTURE DEVELOPMENTS FOR 3D DATA SHARING

### 4.1 Two main user categories and opportunities of on-line interactive data consulting

On the side of the future development, it is expected to carry on the research under the three-dimensional usability by different user typologies. In particular there have been identified two different kind of access typologies:

- a 'home' user, that can access the information through a standard interface that supports the virtual navigation;
- a 'professional or practitioner user' within an interdisciplinary approach able to access the information through an interface to be developed considering the aims and the objectives: the most important features will be the 3D data visualisation and the interactive data usability, contemporarily with other users as well as multiple function tools.

The 3D data for the home user will be available in the X3D/VRML format and usable through the several players (such as Adobe Flash Player, Adobe Reader, QuickTime, Autodesk Design Review).

For the 3D data to be viewed by the practitioner or different specialist involved by the research there will have to be developed an interface ad hoc in accordance with the "WEB3D Consortium" directives for the real time transmission of 3D data through the network and applies.

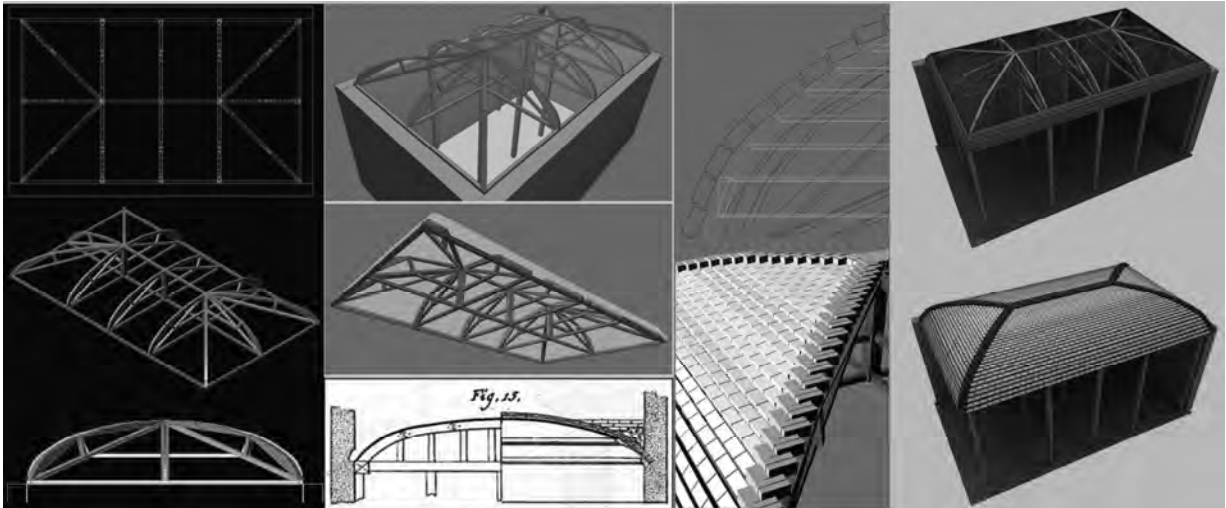


Figure 6: The steps of three-dimensional reconstruction of the vaults , starting with laser scanner data and considering historic construction methodologies

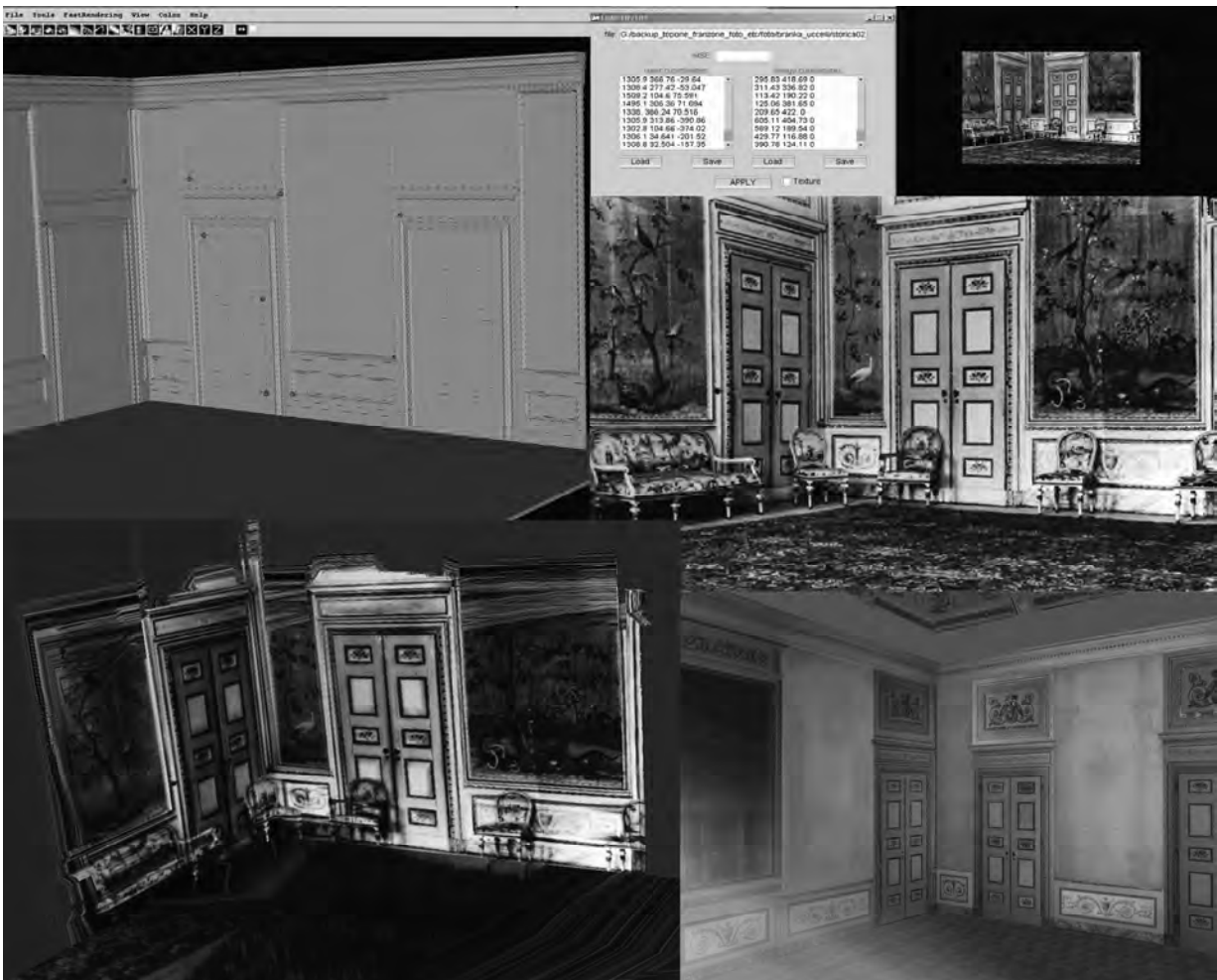


Figure 7: From left up, clockwise: Virtual reconstruction of a historic scene of *Sala degli uccelli* (The room of the birds) - the steps of the internally developed software in order to support the photogrammetric projection of the historic digitalized image on the 3D-model constructed from laser scanner and geometric survey data. In the beginning basic projection algorithm of DLT has developed the bundle adjustment tool and co-linearity constrain for internal and external orientation and parameter estimation

The development of the specific interface should be oriented to the implementation of a remote work environment to share three – dimensional data throughout the web, today not available on the web software market. In the system development, the most modern web technologies, such as ASP.NET 3.5, AJAX, X3D, will be used.

The research focus here explained, are being developed during the last 4 years at the Elab3DPOLI (Lab of Photogrammetry Survey, GIS) within the implemented open source software named MIMO. In particular, the research programme, financed by doctorate programme fellowship, is focused on implementing an interactive virtual environment from advanced platform (web 2.0). The topics on developing are the following: Modelling, sharing and real time modifying of 3D multi-sensor data (laser scanner and photogrammetric ones) using the technologic standard (i.e. X3D and AJAX). The informatics competences required in order to use the standard typologies such as X3D e AJAX are finalized to the remote common sharing of integrated metric models, made measurable through the orthophoto projection of every single room and of its own box diagram.

#### 4.2 Future employment of technology for different type of 3D data sharing

The revitalization process of the Villa Reale di Monza, presents some complex innovative aspects not well indicated until now by objectives, strategies, and instruments: for this reason it can be considered a relevant pilot case, within which the promoter, Regione Lombardia, (the owner of the large part of the monument) had involved, at different levels, some of the main institutions and Universities (Politecnico di Milano and Università Bocconi - Economic aspects).

The problems of the economic feasibility of the restoration , given the dimension and the conditions, need to study and verify also the possibility of connection between the concept of valorisation of the cultural heritage and the conservation aims, identifying as well the incoming conditions in order to predict the participation of privates, both as far as the investments on valorisation and management and the maintenance control of the object in the future is concerned.

This case should demonstrate the innovative potentials of the methodology of programmed conservation that aims to overcome the logic of restoration as an exception or an isolated event in the time, in favour of a progressive vision of a conservation that exploits the economic convenience of the programming, considering the post damage intervention, the prevention and the rationality of sustainable use.

The priority is represented by the identification of a methodological process able to answer this aim, by defining an operative model able to support the identification of 'significant 'sensible data'.

#### 4.3 Sustainability protocol for the management and programmed maintenance of Cultural Heritage

The objective of this document is to define a sustainability protocol for the management and programmed maintenance of the heritage, that would guarantee the conservation, valorisation and control over the time for, beginning from the results obtained and the technological modules developed until now, in

particular, the Sircop module and the e-VmV module here explained.

The Sircop module is a module of a Informative System developed in the form of a DBASE to support ordinary maintenance process\*. The aim is the development of an innovative field of programmed maintenance to be managed in the future, using as a sample test the case of Villa Reale: a dynamic approach of an adaptive methodology supported by development of the e-VmV in connection with Sircop for real time analysis, control, alert, prevention and intervention programming. Amongst all, the survey of the whole stress impact on the monument through the punctual analysis of different percentage (climate aspects, sustainable rated load and the effective one, frequencies of vibration, degree of alteration etc.) from which experts could: derive the impact factors within the programmed maintenance and in function of the dynamic developing over the time, quantify the phenomena and therefore perform remote transmission/communication in real time emphasising the interdisciplinary approach and cooperation within the field of Cultural Heritage conservation.

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<http://asp.net/ajax/>

<http://www.w3.org/WAI/>

<http://www.w3.org/MarkUp/>

\* Cfr. AA.VV, *La Conservazione programmata del patrimonio storico-architettonico. Linee Guida per il piano di manutenzione e il consuntivo scientifico* (Programmed conservation of historical and architectural heritage: guidelines for the maintenance programme and the scientific final balance) by Cannada Bartoli N. and Della Torre S., Regione Lombardia- IReR, Guerini e Associati, Milano 2003



# **Cultural Heritage Resource Information Systems**



## COME BACK TO THE FAIR

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### ABSTRACT:

*Come Back to the Fair* provides a 3D interactive experience that conveys the themes, architectures and relevance of the 1964/65 New York World's Fair. The goal of this project is to present visitors to this venue with the opportunity to understand the decade of the 1960s and its influence on our current world through an interactive journey that connects the scientific themes of the fair with the artistic expression and human context of the event. These connections are made through free-choice exploration of virtual models of the Fair's pavillions and interaction with avatars that are informed by experts who help visitors make the connections between the scientific content and its cultural context.

### 1. INTRODUCTION

*Come Back to the Fair* is an interactive journey unfolding the events, sights, sounds and personal reflections of the 1960s through the lens of the 1964/65 New York World's Fair. More than a simple architecturally accurate representation of the Fair – the 3-Dimensional environment serves as an interdisciplinary platform for interaction with the era through exploration, guest speaker avatars, programmed avatars, games, photographs, and documents. Its interactive delivery affords educators and the general public unfettered access to explore. Through the myriad of pavillions it offers links to numerous disciplines – science, engineering, technology, national and international political/cultural affairs, religion, art, history and architecture.

### 2. DEVELOPMENT PHASE I – ARCHITECTURE

The initial goal of *Come Back to the Fair* was similar to that of several 3D virtual heritage endeavors that focus on World's Fairs – historically accurate reconstructions of structures. The Institute for Advanced Technology in the Humanities (IATH) at the University of Virginia reconstruction of the Crystal Palace from the 1851 Great Exhibition offered an architecturally detailed reconstruction of the famed structure (Jessee and Rourke, 2001). While virtual visitors could once again experience Joseph Paxton's magnificent edifice, the project did not reconstruct the exhibits nor did it place the Crystal Palace into the context of the period. While other disciplines can glean some information from this reconstruction, this project can be classified as one of a single discipline – architecture. Virtual visitors have no understanding of the Great Exhibition's significance within the history of Victorian Britain.

The Urban Simulation Team (UST) at the University of California Los Angeles is currently involved in a recreation of World's Columbian Exposition of 1893 (Jepson, 2008). This project differs in several aspects from that of the Crystal Palace. Encompassing over 600 acres along Chicago's lakefront, this Fair was significantly larger than that of 1851's Great Exhibition. Users can experience the project through a CAVE at

UCLA where the “real-time visual simulation technology” permits navigation through the completed areas of the Fairgrounds. While there is consideration given to the Fair beyond its architectural splendor, other disciplines are not built directly into the 3D environment. Users need to be on site and a human guide is required to place the Fair within the context of the period and provide a greater understanding of each pavilion. While the environment itself is centered on architecture – the overall project has interdisciplinary potential given the CAVE guides.

### 3. DEVELOPMENT PHASE II – HUMANITIES

The leap from architectural reconstruction to conveyor of humanities content is quite natural with World's Fair subjects. By their very nature, World's Fairs are temporary events that provide a panoramic snapshot of an era. They depict the hopes, aspirations, fears and faults of a society. The Great Exhibition of 1851 served as a showcase for Victorian technology and cultural arrogance. Visitors to the 1893 Columbian Exposition in Chicago found a carefully crafted landscape that brought together new technologies, cultural treasures and Gilded Age excesses. When New York welcomed the world to Flushing Meadows in 1964/65, Fairgoers found a celebration of post World War II American prosperity, Space-Age wonder, Cold War fears and a changing international stage.

Virtual reality technology transports the mind beyond the 2-dimensional bounds of text or photographs; it engages the imagination and forges visual links. The initial goal of the National Endowment for the Humanities funded project saw *Come Back to the Fair* as a 3-Dimensional spatial interface to navigate mixed media Internet based archives. Utilizing the OGRE (Object-Oriented Graphics Rendering Engine) engine, *Come Back to the Fair* provides for full free first-person perspective exploration of the 1964/1965 NYWF fairgrounds. Although conventional photos and archival film footage can convey the general feel and provide details to the NYWF, they cannot demonstrate the spacial connection between the myriad of pavillions at the Fair. A highly detailed and interactive 3D



environment can provide access to the full breadth of archival resource materials via direct hotlinks to digitized holdings pertaining to the NYWF. When exploring the virtual Fairgrounds ‘archive photo spots’ designate archival interface points. Each of these ‘archive photo spots’ provides access to archival photos that are real images to the viewer’s precise perspective in the 3D world. (See Figure 1 for visualization of “archive photo spot feature.”) For example, if a virtual Fairgoer were to access an “archive photo spot” offering a northeast view of the Stegosaurus in Sinclair *Dinoland* they would see this perspective in the 3D world and the “archive photo spot” offers actual photos at an identical angle. This provides unparalleled contextual understanding of every image within the archive. The immersive 3D NYWF environment serves as an interface to introduce users to a new search tool for primary source archives.



Figure 1: Hall of Science Pavilion with “archive photo spot”  
The 1964 Kodak camera to left provides access to the interactive image gallery.

Fairgoers enter pavilions and view a wide variety of primary source materials pertaining to that pavilion’s interior and exhibits – photographs, official documents, promotional materials, and video. Essays place the pavilion and its exhibits into historical context. Take as an example the IBM Pavilion; upon exploring the building’s unique exterior, visitors can virtually ride the “People Wall” as it ascends into the “Information Machine” or they could view concept cars in the Ford Pavilion. (See Figure 2.) Once inside the pavilion virtual Fairgoers can examine photographs, documents and video pertaining to the IBM pavilion. Essays examine computers in 1964/1965, describe how the IBM pavilion attempted to ease public concerns regarding the future use of computers, and recommended additional readings/websites (Highmore, 2004). Each visitor is equipped with a virtual ‘official’ Fair guidebook that serves as an additional interface to documents and essays for each pavilion.

Programmed non-player character (NPC) avatars are planned and will assist in facilitating an understanding the events of 1964/1965 America beyond the physical boundaries of the Fairgrounds. Upon entering the virtual environment Fairgoers can select their visitation date from within the two Fair seasons. A virtual Fairgoer who selects 22 April 1964 would experience opening day activities including Congress of Racial Equality demonstrator NPCs at selected pavilions, President Lyndon

Johnson’s address at the Singer Bowl, as well as NPCs who might discuss the Broadway play they were planning on seeing that evening. The avatar interactive experience and the issues presented change based on the date the virtual Fairgoer chooses. A real-time interactive avatar community will provide educators an opportunity for virtual field trips.



Actual image of Ford Pavilion



3D model of Ford Pavilion

Figure 2: Real and corresponding virtual model

### 3.1 Development Phase III – Connecting the Humanities

The second phase of *Come Back to the Fair* addressed the science and technology presented at the NYWF purely from a historical perspective – it provided a glimpse into what was unveiled and how it impacted society. But it did not reach across discipline boundaries and directly incorporate Science, Technology, Engineering and Mathematics (STEM) content into the virtual Fair. Phase III of development builds upon the solid humanities content of Phase II. STEM and arts & humanities discovery and interaction unfold through five types of “Conduits” that can combine in unbounded ways to provide a myriad of pathways toward the cross pollination between arts & humanities and STEM knowledge. This is a key concept within the *Come Back to the Fair* environment.

As adolescents explore the 646 virtual acres of the New York World’s Fair, at every turn there is something to discover and interact with. The pavilions at the Fair provide an endless

variety of topics to serve as interest hooks. The environment is dense with structures that prompt desires to see what is around the next turn. In this informal sandbox environment, the emphasis is on self-directed exploration as opposed to a “treasure-hunt reward” or “quest.” Satisfying one’s intellectual curiosity, as opposed to material acquisition, is presented as its own reward.

### 3.2 Conduit One: Encounters with Subject Matter Experts

Subject matter experts (SMEs) appear as avatars within the environment interacting with and explaining examples of themes presented at the Fair. Two categories of subject matter experts are stationed throughout the Fairgrounds: period and contemporary experts. The period experts facilitate the intergenerational knowledge transfer as they unfold for a new generation their tales of historically significant events with which they were associated, analyzing the development of the subject and vividly describing its significance within history and culture. For example, at the space park outside the Hall of Science, an aerospace engineer who served as test conductor for half of the manned Project Mercury launches interacts with visitors not only discussing the STEM value of the Mercury missions but their importance within US culture. While outside Sinclair’s *Dinoland* a contemporary paleontologist may discuss the evolution of paleontology since the 1960s or a political scientist outside the *Equitable Life* pavilion addresses the consequences of population growth.

### 3.3 Conduit Two: “Hands-On” STEM Discovery Points

Throughout the environment, STEM Discovery Points afford opportunities for in-depth interaction with STEM topics. At a discovery point that links the Fair’s “Wonderful World of Chemistry” experience to a virtual chemistry lab, visitors can observe and conduct accurate virtual experiments such as creating nylon fibers or an ablative material for a space capsule heat shield. In the virtual world the costs of chemicals and equipment are irrelevant, so experiments can be repeated numerous times to allow for curiosity and exploration in the truest sense with no danger to participants. (See Figure 3 for a 1960s activity that allowed visitors to create their own models through the wonders of modern chemistry and 25 cents.) In addition, experimental discovery extends to awareness concerning the on-going relevance of the experimental results: these synthetic materials developed during the 1950s and 1960s continue to permeate almost every aspect of contemporary life. A secondary component of this discovery point, then, presents a typical house of today that has been equipped with material and time dials so that users can begin to add or remove selected items from the household to reinforce the continuing relevance of these items.

Arts and Humanities Discovery Points further strengthen links with STEM and the cross pollination between disciplines. For example, Michelangelo’s *Pieta* served as a cultural centerpiece at the Fair. Looking beyond its beauty, this sculpture is a triumph of mathematical prowess. Similarly, works of art by Goya, Rubens, and Picasso shared the stage with the New York State Pavilion’s vast wall of pop art headlined by Andy Warhol’s contributions. Having learned about the influence of mathematics in the creation of painting and sculpture, virtual Fairgoers enter a discovery point that allows them to experiment with perspective and geometry in art.



Figure 3: Mold-a-Rama machine demonstrates level of detail within environment

### 3.4 Conduit Three: Connections and Relevance

Connections Portal Points permit the virtual fairgoer to explore myriad social, aesthetic, technological, political, economic, and cultural influences of the mid-1960s. These portal points embedded within the Fair environment offer the opportunity to explore interdisciplinary connections. The goal of these portals is to create an engaging web experience for digital natives by which they can extend their knowledge through individualized digital information journeys that grow out of their interactions with the virtual environment. The Fair presents an ideal lens through which to address a wide range of topics pertinent to the era, whose impacts are felt to this day.

- 1) The Grand Central Parkway and Long Island Expressway surrounding the Fairgrounds were by-products of the Fair’s construction. These are not simply massive engineering efforts, they afford an excellent opportunity to discuss post World War II suburbanization and its impact on large urban centers.
- 2) Congress of Racial Equality (CORE) members encircled the Unisphere in 1964 to protest the inequality of civil rights within the nation. This event foregrounds an important aspect of the cultural history of that era and readily lends itself to comparisons with the world we live in today.
- 3) Unlike previous World’s Fairs, newly independent African republics addressed their cultures free of colonial interpretation – affording the opportunity to explore both culture and the collapse of colonialism in the post World War II world.
- 4) Japan’s pavilion was used as a platform to transform the American mindset of ‘Made in Japan’ from an association with inexpensive and low-quality goods to one of craftsmanship.
- 5) The massive IBM O/S 360 computer unveiled at the Fair foreshadowed the ubiquity of computers in modern life.

### 3.5 Conduit Four: Virtual Exploration

What makes a virtual environment compelling is its ability to enable interactions that are impossible in the real world. Only in a virtual world, for example, could a 10 year-old launch a Mercury astronaut into space. Building upon assets created for the *Shadows of Canaveral* project, adolescents will be able to travel from the Rocket/Space Park at the NYWF, where astronaut Scott Carpenter's Mercury capsule was displayed, to Cape Canaveral, Florida, to take part in the excitement of a real space mission. Once briefed on the physics of spaceflight, adolescents can even try their hand at orbital flight.



Figure 4: Interior of Mission Control at Cape Canaveral

A myriad of other interactive exhibits are possible for virtual fairgoers. Perhaps within the Ford Pavilion, they could view Jimmy Clark's Formula 1 racer. A simulation could allow participants to virtually dissect the Formula 1 and thereby understand its mechanical workings and how aerodynamic forces impact the racer.

### 3.6 Conduit Five: Consequences

World's Fairs are celebrations of new technologies paired with crystal ball visions as to how these technologies will alter the future. This Fair offers an expansive array of future visions ranging from telecommunication satellite networks to equipment massive enough to plow through the jungles to open the riches of the Amazon for all humanity. Within the General Motors Pavilion, they could experience *Futurama*. An expansive exhibit/ride, this mid 1960's glimpse into the world of 2024 foretold how science and technology would shape the world in which today's youths will ultimately inhabit,

Of course, all technological innovations have consequences; this area is dedicated to the exploration of such consequences. Through analysis of selected items, participants come to understand that addressing one issue may give rise to many others. In attempting to help alleviate one set of problems, in short, you may in fact set in motion a series of unintended consequences. And while the crystal ball into the future does not exist, this Conduit's installations illustrate to participants that today's solutions may in fact become the problems of tomorrow. This 20/20 hindsight instills an awareness of consequences and reminds participants of one of the risks attendant to innovation. Conduit Five installations are prime sites at which to help participants temper the fast-paced and forward-looking excitement of STEM developments with the

reflective demeanor of the arts and humanities. They encourage participants to reflect on the types of thinking that could have mitigated the sorts of post-industrial consequences we contend with today.

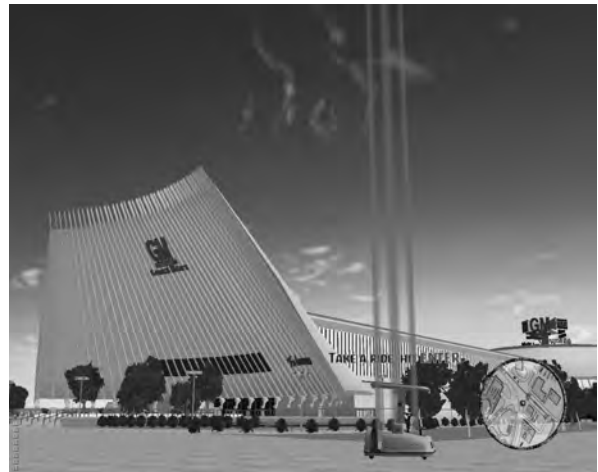


Figure 5: Exterior of General Motors Pavilion. The orange lines serve as a rotating marker for the Greyhound Escorter interactive ride feature available to Fairgoers.

## 4. FUTURE EXPANSION

Upgrades serve as a prime attraction of commercial Massively multiplayer online role-playing games (MMORPGs) in that they provide a constant supply of new avenues to explore. This is a marked shortcoming of many educational games; once they are created they become static in their evolution. The virtual New York World's Fair environment provides a myriad of expansion opportunities that will entice individuals to re-discover and continue to use the environment. New environment instances can be extended from the wide variety of pavilions at the Fair, thus creating new opportunities and levels of exploration.

## 5. AUDIENCE

The core target audience for *Come Back to the Fair* is the 9- to 13-year-olds - adolescents and immediate pre-teens - and by extension their families and the general public. This group is part of what noted educator Marc Prensky defines as the digital native generation (Prensky, 2001). The digital revolution they enjoy has not only dramatically expanded access to information; it has simultaneously altered the manner in which individuals acquire knowledge. The Internet, PDAs and iPods are not simple conveyors of information; they have evolved into societal tools. Digital native youths are not only comfortable with digital technologies, they expect them. Educators are faced with the challenge of merging the interactivity and visualization that this multi-tasking digital generation enjoys, while maintaining effective intergenerational transfer of knowledge.

The 9- to 13-year-old subset is targeted because, although they are old enough to understand the content being presented, they have yet to internalize the siloed views toward disciplines that tend to develop as we advance through life. They have, however, reached a point of gender awareness and stereotyping. Virtual worlds provide immersive experiences where users are

compelled to explore. Between the ages of 9 to 13, youths have an intense desire to understand and explore, but they are fettered by peer pressures. Both young girls and boys fear societal stereotypes regarding the sciences and humanities. Virtual worlds are ideal environments within which youth can escape such pressures to explore and participate freely (Clarke and Dede, 2005). In virtual worlds, youth can indulge their curiosities through interaction with quality humanities and STEM content. *Come Back to the Fair* demonstrates that many great leaps in the advancement of the humanities, science, and technology have been made when people looked beyond discipline boundaries and wondered “what if?”

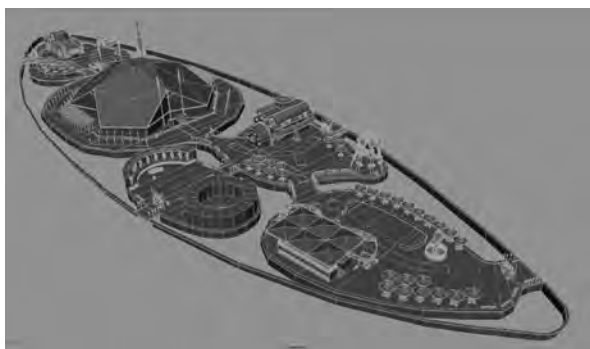


Figure 6: Wireframe of Chrysler Pavilion Island

## 6. CONCLUSION

World's Fairs are born from a societal desire to showcase the wonders of science and technology; these showcases are then realized visually and experientially by means of the arts and humanities. As such, virtual reconstructions of World's Fairs are ideal conduits to explore all aspects of a time period in an environment that is comfortable to the digital native. The vast sandbox environment provides free roaming exploration of mid-1960s America. Rising from the skyline immediately beyond the Fair were vast public housing projects which can provoke discussion on the history of low-income housing. Protesters against the increasing involvement in Vietnam circled the Unisphere in 1964. The automobiles unveiled at the Fair can invite analysis of the history of US auto manufacturing or of Ralph Nader's then recently published *Unsafe at Any Speed* (Nader, 1965). Over 140 pavilions provide an opportunity to address a full range of topical issues – from manned space exploration and the Berlin Wall to Hollywood motion pictures, novels and music. The Fair serves as a central hub to a myriad of individual topical avenues pertaining to the 1960s. As digital

native travel through the 3D NYWF environment they can realize the interdisciplinary links between STEM and the arts and humanities. Connections are a fundamental mechanism of innovation and many an individual looking beyond traditional bounds has helped to launch a revolutionary advance. *Come Back to the Fair* helps 21st-century learners understand where ideas come from, and thereby helps them begin to map where the future may take them.

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# THE COMMUNICATION MODEL OF THE ANTHROPOLOGY MUSEUM: CASE OF MULTIMEDIA INFORMATIONAL-EXPOSITION COMPLEX OF THE ST.-PETERSBURG KUNSTKAMERA

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**KEY WORDS:** multi-channel communication, anthropological tagging, content streaming, “museotheque”

## ABSTRACT:

Peter the Great Museum of Anthropology and Ethnography (Kunstkamera) of the Russian Academy of Sciences is one of the oldest museums in the world; it was founded by Peter the Great in 1714; its collection numbers about 1,900,000 pieces. It is the leading research and museum institution in Russia that deals with the study and informatisation of world people’s cultural heritage, traditional cultural, social anthropology, physical or biological anthropology, archaeology, and museum studies. The project of Multimedia Informational-Exposition Complex of the museum offers a sort of “museotheque” with wide variety of methods for both in loco and online visitors to access the best anthropology collection in Russia. Innovative methods of knowledge acquirement, cognitive interaction, and involving institutional activities allow the visitor to share in the collective experience while exploring the museum.

## 1. INTRODUCTION

The Multimedia Informational-Exposition Complex project of the Peter the Great Museum of Anthropology and Ethnography (Kunstkamera) of the Russian Academy of Sciences (MAE RAS) began as a result of collaboration between the MAE RAS and the St.-Petersburg Foundation for Investment Projects (FISP) with its Cultural Investment Facility (CIF). The main objective of the project was to create a new knowledge-based context for understanding, interpreting, managing and disseminating data concerning anthropology and history of science heritage preserved at the museum.

Before the project implementation inventories of museum collections have been kept in paper copies and were often inconsistent and incomplete. According latest initiatives of the Ministry of Culture of the Russian Federation categories of cultural heritage have been defined and put into the State Catalogue of the Museum Fund as single inventory of national cultural heritage. However still there is no state cultural heritage inventory system in Russia as an all-inclusive national inventory. That’s why every museum creates its own collections management database using different collections management software existing on local market.

Most of such databases developed over last decades in Russian museums are oriented on the professional needs of the museum staff in collection inventory and documentation and are not accessible for external users. On the contrary the Multimedia Informational-Exposition Complex project of the Kunstkamera museum is positioned like “museotheque” – data bank meeting informational needs of different users, including museum visitors, students, and other audiences. Main distinction of this innovative approach is providing target group of users information in formats and in quantity they require through subsequent types of media entries, systemized and kept in the museum database.

## 2. THE PROJECT

### 2.1 Aims and Objectives

The main objective of the project was to create a new knowledge-based context for understanding, interpreting, managing and disseminating data concerning anthropology and history of science heritage preserved in the museum. Another objective was to widen and diversify the types of cultural heritage artifacts and materials traditionally acquired by museum through intensifying work with untouchable heritage. The Multimedia Informational-Exposition Complex (MIEC) is a core for anthropology data management as well as a proactive tool for the use in many museums of Russia. This is one of most effective ways in which cultural heritage can become widely accessible for professionals and public and thus contribute to the improvement of the quality of life in contemporary Russia as a multi-national society. It also makes a considerable contribution to the development of information society in general, reconfiguring the way of museum acquisition dramatically.

On a technical level, MIEC aims at providing real-time indexing, capture, processing and recording of data. All the data is stored in a relational database, which has some Internet capabilities. The indexing of the records was done according national standards, which incorporate international ones, but data input often exceed them in terms of consistency and knowledge richness. Data entry redundancy, reconciliation and accuracy of input were basic principles of data validation.

### 2.2 Implementation

The project has been specially adapted to its visitors’ perceptions, using data acquired through an ongoing investigation begun in 1998 (Bogomazova, Uzunova 1999; Bogomazova, Bronnikov 2000; Bogomazova, Malevanov, 2000; Bogomazova, Malevanov, 2001; Bogomazova, Itskova 2003). One of the primary goals of the project was increasing the content-streaming capabilities of the Museum through

various digital devices operating both individually and in tandem, providing adult visitors and children with information on the cultural and social anthropology of world peoples.

MIEC consists of several main applications, constituting its framework. All together they meet the following requirements:

- maintain national standards;
- encourage open source approach;
- facilitate data reuse;
- safeguard scientific accuracy through multidisciplinary study;
- provide interoperability;
- combine presentation with interpretation;
- exploit all available information sources of the museum.

Technical and content foundations of the project were implemented in 2005-2007 and are actively developing now. According to the contract with FISP, the Project was divided into three phases, namely an initial phase for conducting an analysis of the MIEC requirements and to design it, a second phase for data collecting and migration of already existing heritage data in electronic format, and a third phase during which the Complex was developed, implemented, and tested.

### 2.3 Infrastructure

The infrastructure of the projects consists of two main parts:

1. Administrative part;
2. User-oriented part.

Administrative part consists of the relative DB and a number of networked data input terminals housed in the working space of the museum.

The user oriented part is housed in museum rooms and includes the following applications:

1. Navigating application;
2. Multimedia knowledge application;
3. Guide's application;
4. Kid's center application.

*Navigating application* includes graphic schemes of the museum rooms (Africa, Japan, Northern America, India and Indonesia, Indochina, China and Mongolia and Korea, Natural scientific collection) with 286 museum show-cases of different sizes, which were sophisticatedly graphically marked capturing all 5,500 exhibits of the museum permanent exhibition. Every exhibit has the following attributes:

- vector graphic unique contour space locator, recorded in the DB;
- detailed information about the object indexed by the means of specially designed anthropology tagging system;
- high resolution photo in several perspectives with strong zooming capabilities;
- at least 50% of exhibits are annotated in a way that ensures effective and complete interpreting of their symbolic context or/and function.

Navigating application is available at every museum room and offers every visitor of the museum opportunity to locate himself in museum interiors and find most comfortable route of thematic or overall tour round the museum exhibition.

*Multimedia knowledge application* includes thematic modules for Africa, Japan, Northern America, India, Indonesia,

Indochina, China, Mongolia and Korea. Every thematic module includes:

- a set of maps;
- hierarchy of articles describing geography and cultural anthropology of a region (more than 400 pages);
- illustrations (more than 5 000 images) – both museum objects and field photos;
- video recording and documentary (more than 3 hours);
- audio recording (more than 2,5 hours).

Multimedia knowledge application is available at every museum room and offers every visitor of the museum opportunity to get basic text information and rich visual information for personal exploration of world cultures. Vivid multimedia streaming realistically portrays symbols, rites, and human values from all around the world, allowing the visitor to make a mini "world tour" during one or several museum visits, both in person and online.

*Guide's application* is protected by a password tool for museum guides providing them opportunity to collect and present to groups of visitors any information available in other applications, including texts, photos, video, audio and games. They are very effective for international groups and thematic excursions and allow diversifying content stream for different channels and users, both *in loco* and distant. The application can be easily accessed by all interested audiences, locally and internationally.

*Kid's center application* is designed for Kid's Center located on the ground floor of the museum. Its networked equipment allows access to any application of the MIEC. Also it contains customized animated games based on folk myths and fairy tails. Another feature is DB-based modules providing opportunities of knowledge control and training in an entertaining form of questionnaires, quiz and lotto thematic games, which are open for editing and transformation, input of illustrations and multimedia objects. Personnel of the Kid's center are trained to create and edit these games for educational needs of any age and knowledge level.

The project has improved institutional infrastructure of the museum through establishing of the museum's Methodological Collections Management Database Committee, the Department of Information Technologies, the Department of Technical Computer Service, the Kid's Centre, etc. Today the MIEC is supported by 45 administrative work stations set all round the museum.

### 3. THE TECHNICAL SOLUTION

MIEC was developed with KAMIS technology which is one of the leading cultural heritage inventory software products in Russia, applied in more than 200 museums.

KAMIS is based on advanced Oracle DBMS in client-server architecture and ensures automation of all essential aspects of museum information activities. It is highly configurable system and comes with multiple search and viewing options and customizable thesaurus. Collection information is divided into a number of customized integrated modules, such as Objects, Events, Exhibitions, E-kiosks, Web-publishing. It enables collecting information through improved inventory control and

accountability. Simultaneous work of unlimited number of networked stations is ensured by high reliability, safety, and fail-safe operation rates. Information in any language and with different symbols can be input in the database.

By the means of KAMIS software MIEC is able to:

- track loans and exhibitions;
- issue and store inventory and conservation documents in text and Word format;
- keep logbooks;
- describe objects from different modules forming detailed passport with many attributes;
- provide fast data search and retrieval, including quick search and extraction of data by various attributes;
- run museum collections management: inventory cards, scientific passports, prepare various kinds of lists and catalogues;
- commit web publications and catalogues.

Any database query results can be exported into various customized formats, such as text, PDF or XML.

#### 4. CONCLUSIONS

It is envisaged that the experience gained through the development of the MIEC project can be beneficial to neighbouring countries. The aims of the MIEC share identical concerns in cultural heritage management and interpretation. The applications developed can be readily adopted and adapted for the inventory, presentation, decoding and management of cultural heritage within anthropology museums of other regions and countries.

Continuation of the project envisages two main aspects. The first is replenishment of considerable corpus of photo and archival data though further digitizing, retro conversion and flow line input materials from Eastern Europe, Siberia, Central Asia and Caucasia.

The second is introduction of new technologies into the Complex – development of Web 2.0 Internet applications, podcasting, mobile, wap/pda technologies.

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## DESIGNING INTEROPERABLE MUSEUM INFORMATION SYSTEMS

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**KEY WORDS:** Digital Museum, Management Systems, Digital Assets, Interoperability, CIDOC/CRM.

### ABSTRACT:

Museum collections are characterized by heterogeneity, since they usually host a plethora of objects of categories, while each of them requires different description policies and metadata standards. Moreover the museum records, which keep the history and evolution of the hosted collections, request proactive curation in order to preserve this rich and diverse information. In this paper, the architecture of an innovative museum information system, as well as its implementation details is presented. In particular the requirements and the system architecture are presented along with the problems that were encountered. The main directions of the system design are (a) to increase interoperability levels and therefore assist proactive curation and (b) to enhance navigation by the usage of handheld devices. The first direction is satisfied by the design of a rich metadata schema based on the CIDOC/CRM standard. The second direction is fulfilled by the implementation of a module, which integrates the museum database with a subsystem appropriate to support user navigation into the museum floors and rooms. The module is expressed as a navigation functionality, which is accessed through handheld devices and peripherals, such as PDAs and RFID tags. The proposed system is functional and operates into the Solomos Museum, situated in Zakynthos island, Greece.

### 1. INTRODUCTION

Museum collections are characterized by heterogeneity not only regarding their collections, but also due to the plethora of the different services they provide. It is typical for a museum to provide its employees with tools for collection management through different metadata schemata, collection history and evolution, web site management, collection information preservation etc. Having entered the information age, modern museums provide their visitors with services like interactive tours (through mobile devices), educational applications, etc.

In order to provide all these services, a complex information system is required. In this paper, an information system is presented integrating a number of innovative services and has been in operation for the last year in the Solomos Museum situated in Zakynthos island, Greece. A basic requirement of the system is its compatibility with the CIDOC/CRM standard. Thus, all the information inserted in the museum database must be mapped to the CIDOC ontology.

In the following sections the architecture of an information system called Digital Museum Management System (DMMS) is presented along with its application study and the challenges that arise during its development and operation.

### 2. RELATED WORK

The growth of cultural heritage information systems field and the maturing of ideas, concepts and demands have lead to the evolution of software applications to address the numerous needs that each and every phase of digital museums requires. Digital museum management systems are growing in number providing a set of options, but also are exhibiting remarkable quality leverage. The MuseTech Registry (<http://www.musetechcentral.org/>), which is jointly developed by the Museum Computer Network and the Museum Software

Foundation, lists several digital museum applications in areas like digital asset management, collection management, publication, digitization, gallery and kiosk development and so on. This highlights the increasing and varied demand in specific areas of the museum information flow and the mature response of the community.

Regardless of the system development approach, two issues are explicitly required in digital museum applications; system flexibility and adaptation to user needs. The satisfaction of these two requirements faces many difficulties due to the heterogeneous material hosted in museums. In a museum a variety of two and three-dimensional objects may exist, such as pictures, clothes, furniture, etc. Moreover a diversity of visitors have access to its physical and digital collections, with different goals, e.g. educational, research in several domains such as history, archaeology, anthropology, sociology, etc. and of course for touristic and entertainment purposes. Referring to digital collections, metadata schema design is a very crucial process which is closely related with the fulfilment of the mentioned requirements since it is the mean for managing and revealing all the important attributes of the museum collections. As Chen et al. (2002) report, there are seven stages in metadata development, namely analysis of collections' attributes, collection and analysis of user, interoperability, semantic design of metadata, development of metadata management systems, development of tagging guide and user manuals and provision of training courses.

Moreover the enhancing capabilities that the technology provides allow viewing the museum objects management under various perspectives. The proliferation of specialized museum management software gives the chance to detach useful information from application types and models of interaction that belong to other domains. Tang proposes new ways of presenting and accessing digital objects and collections in a digital museum that are adjusted to the contextual needs



emerged by this environment, such as narrative-centred, object-centred and information centred (Tang, 2005).

Patel et al. (2005) respond to the metadata creation challenge for museum application by approaching not only the systemic aspect of development, such as functional requirements or interoperability, but by giving emphasis to the user requirements as well. They emphasize on the role that each user class has in the development of museum metadata.

### 3. SYSTEM DESCRIPTION

Typical design requirements of a digital museum management system include:

- The comprehensive and precise recording of the cultural heritage items.
- The security and integrity of the digital assets and its respective metadata.
- The support of effective administration and documentation of the digitized material.

The proper design of an application acquires great importance in museum applications for two reasons: (a) the museum items in a variety of forms (such as two dimensional items - paintings, documents, manuscripts and incunabula - and three dimensional items - sculptures, music instruments, guns and armory) and carry meaningful information which need particular handling; (b) furthermore the corresponding metadata are often used by a variety of applications, like websites, portals, interactive applications and mobile computing devices, and therefore different views of the same information are required in order to augment the technical aspect of the contextual information retrieval.

#### 3.1 Syntactic Interoperability

Referring to the information structures that are required for cultural heritage documentation, three categories of metadata element occurrence are needed for the proper description of an item:

- *Necessary*, where element and subelements values are indispensable for the correctness of the record.
- *Mandatory*, where element and subelements values are given if they exist and are known to the museum personnel.
- *Optional*, where element and subelements values are given if the data exist and when the economy of the whole process allows it.

Furthermore each field can receive multiple values if the precision and the extensiveness of the record request it. Therefore the level of multitude of values is divided to the following categories:

- Unique, where only one value is required and allowed.
- Multiple, where more than one values are allowed.

The above mentioned syntactic rules could be expressed by an XML Schema which defines a metadata language able to express and exchange machine readable metadata structures.

#### 3.2 Semantic Interoperability

In order to achieve a satisfactory level of semantic interoperability, the default metadata schema of the application was designed in order to support correspondence with the CIDOC Conceptual Reference Model (CIDOC/CRM) (Kalomoirakis et al., 2005). CIDOC/CRM is jointly developed by CIDOC Documentation Standards Working Group and CIDOC Special Interest Group in CRM, while from September 2000 it is a draft ISO standard (ISO/CD21127). The principal aim of CIDOC CRM is “to enable information exchange and integration between heterogeneous sources of cultural heritage information” (ICOM/CIDOC Documentation Standards Group, 2008). In particular CIDOC/CRM aims at the standardized expression of cultural information and the semantic definition of concepts and relations, which are needed for local access constraints. According to formal target statements CIDOC/CRM aims to “serve as a basis for mediation of cultural heritage information and thereby provide the semantic ‘glue’ needed to transform today’s disparate, localised information sources into a coherent and valuable global resource”, but also allows potential extensions for adaptation reasons in specialized applications. CIDOC/CRM does not dictate the data for cultural documentation, like for instance standard types of terminology, which may derive from the specific character of the collections, but premises the need for a common platform of documentation and interpretation of cultural events and concepts. CIDOC/CRM in application settings consists of an object-oriented semantic standard, which may be transformed into machine readable formats, such as OWL.

#### 3.3 Records Management

The application addresses needs of (a) digital surrogates import and (b) metadata import and editing, in order to create the appropriate information items for the end-user applications. In detail the application allows the following activities to be performed:

- *Import of high and low resolution digital images.* During the creation of a record the authorized user can import a digital image, which corresponds to the physical item of the museum. Finally the user can choose a digital surrogate and edit them with other assisting applications in order to improve their quality.
- *Import of descriptive data of the digital items.* Authorized users can import all data available to describe and identify accurately the specific item, like name, number, way of acquisition etc. During this stage the user can assign potential relationships between the items, to import descriptive texts, to import multimedia files and so on.
- *Metadata editing.* Authorized users can edit metadata for correction or enrichment purposes of the existing records.

The metadata import interface is exploiting data entry techniques in order to eliminate chances of mistyping or to quicken the process. Also implements the creation of authority files for names and terms in order to ensure uniformity and cohesion in the terms of the database.

### 3.4 Architecture

The main application's database communicates with a second database, called assistant database, which stores duplicates of the records in specialized formats linked with the peripheral end-user applications, such as the navigation application. In parallel the assistant database can record the data that are created automatically from real-time interaction and to store them for future processes.

By choosing to use two distinct databases, the architecture enhances the security and the integrity of the data. The peripheral applications retrieve data from the assistant database and deliver them to the end-users. Moreover these applications store in the same point the behavioral and interactional data of the end-users. The system does not allow data import or export from and to the main database, protecting thus the digital surrogates and their metadata. The two databases work in parallel for preserving and securing the data in case an external factor leads to faults in the operation of one of them. This approach however has the side effect of the constant synchronization of the two databases.

The assistant database is responsible for the following operations:

- Collection and storage of the end-users' information (identity data). These data are available to the main database in order to identify the user and provide the respective level of authorization.
- Collection and storage of users' behavioral data. The database records data of the users' behavior as they interact and they request information through the various applications. For example the database records data from the users' interaction with the mobile devices within the museum's space, like paths and node points where the user showed interest (through consultation of the RFID cards in various exhibits). Administration of personal data that are collected in the assistant database are in conformity with arrangements concerning protection of sensitive data. Moreover these data are stored and maintained in the assistant database for a predefined period and then are deleted.
- Collection of users' messages/comments. The assistant database collects all comments and annotations the users deposit during their visit in the museum and their walk through the exhibits. The database allows to the end users administration application the view of all message and comments deposited by the visitors, giving thus the chance to increase social interaction infrastructures in the museum.

### 3.5 Classes of Users

Two are the categories of users that have rights to access the DMMS.

- *System administrators*. The specific user class includes the specialized technical personnel of the museum, which operates the database application and the museum information system application. The specialized technical personnel has full rights of administrating structures of the system, such as fields and database tables, while can create new user accounts.

- *Museum personnel*. The specific class of users can access the system after the system administrators have created accounts, which gives them rights to import, edit and delete information items.

The next sub-section presents the modules of the first class of users, namely the system administrators, while the second sub-section presents the modules for the second class of users, the museum personnel.

### 3.6 System Administrators Modules

#### Personal Settings

Through this module the system administrators can edit the settings of their account.

#### Services Administration Module

System administrators are able to create and import new services and modules, while they are also able to edit existing ones. System administrators have to create a new service by following guidelines in the system documentation manual and applying code editing, and shortly after, through the graphical interface, they can activate the new service.

#### User Administration Module

System administrators can add or delete users of the Digital Museum Management System (DMMS). Moreover system administrators have the ability to define the level of access of each user of the application and to grant access rights to specific services.

### 3.7 Museum Personnel Administrators Modules

#### Announcement Administration Module

The museum personnel can import, view and edit announcements regarding the operation of the museum through the application. The Announcement Module can connect directly with the website or the web portal of the museum, without the intervention of a webmaster. The user can import edit the following fields:

- *Title*: The title of the announcement.
- *Text*: The main text of the announcement.
- *Date*: The date of creation.
- *Visibility*: The level of visibility of the announcement.

#### Groups Administration Module

The museum personnel can import, view and edit groups of assets. The application acknowledges that some groups can have items that belong to more than one team. Through the Groups Administration Module, the museum personnel can import data in the following fields.

- *Name*: The name of the group of digital assets.
- *Comments (Personnel)*: Information about the group of assets that addresses to the technical or museum personnel and should not be visible to public.
- *Comments (Public)*: Information and comments about the group that need to be presented to the visitors of the museum in order to comprehend the nature of the group.

- *Visibility*: The museum personnel can define if the information about the group will be visible to all visitors.

### Digital Assets Administration Module

This section is one of the most important of the DMMS, as it offers to the museum personnel the ability to describe the digital assets and correlate them with other entities, like groups of assets or persons. The museum personnel are able to view all available assets, to import a new one and to edit them. However they need to fill a first set of fields in order to create the record, which are:

- *Identity data*: Information that gives comprehensive information for the title of the asset and that identify it among the many assets, like *name* (the name of the museum item), *code* (an identification alphanumeric code of the item in the archives of the museum) and *local name* (a contextual name of the item).
- *Classification data*: Information that classifies an asset in wider entities, like *group* (the name of the team in which an item belongs) and *category* (information about the category in which an item is part of, according to a predefined scheme of the museum).
- *Description and Commenting of the item*: Free text for the commenting and description of the asset, like *description* (a field of free text for the description of the item and its attributes), *comments* (any comments about the item) and *visibility* (the museum personnel defines if the asset will be visible on the website).

After the completion of this first set of data, the museum personnel can navigate through a second class navigation tab-designed bar in order to fill information about the digital asset.

- *General metadata*: This tab contains most of the information that the user imported. New fields (optional) require a characterization of the item (Classification data), information about the creation of the museum item, such as place, date, material, weight, technique, name of manufacturer and authenticity (Manufacturing information), information about the use, such as place, date, purpose, population, season, way of use (Use of item), information about its acquisition (date, place, previous possessors, way of acquisition, e.g. donation), value (price, currency) and formal documents related to its acquisition (invoice, type of document and date), information about its scientific documentation, such as folders and subfolders of related information, and finally information about the removal of an item from the Museum (e.g. way of removal, formal document, date, new possessor and so on).
- *Relationships editing*: The museum personnel can correlate digital assets in order to highlight the collection's structure and characteristics.
- *Text Files*: Entry of texts for the various applications.
- *Media Files*: Entry of media files (images, moving image files, sound files) that relate to the museum item and need to be presented.
- *Bibliography*: Information about books and other items of literature that relate to the item, such as type of literature (e.g. book, article), code, title, file and comments.

- *Exhibitions*: The museum personnel can link the specific item to exhibitions that has taken part.
- *Research*: Information about the type of research that has been conducted based on the specific item, such as type of research, description, date of research, date of report publication).
- *Position*: information about the current position of the item, such as date, position and comments.

### Authority Files Module

This module offers to the museum personnel the ability to import and authorize personal names and subject terms related to the museum items (see Figure 1).

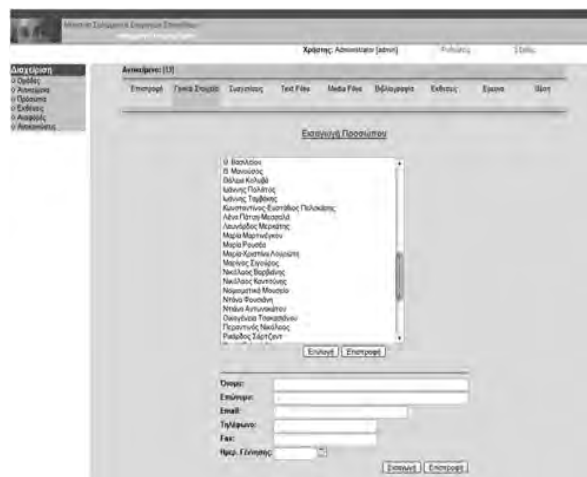


Figure 1: Authority Files Module screenshot of the Application Case Study

### Reports Module

The current module allows the museum personnel to generate reports of multimedia files and their associations with the museum items in the database.

### Exhibitions Administration Module

In this module, the museum personnel can import new entries of exhibitions that the museum items have taken part. The personnel need firstly to create a record for the exhibition and then to relate the item with the exhibition from the Digital Assets Administration Module.

## 4. APPLICATION STUDY

### 4.1 Setting

The scope of the project “*Museum of Solomos, Kalvos and other eminent Zakynthians*” (henceforth Museum of Solomos) was to build a digital repository and to provide a set of services that focused on the support of digital collection management and on the assistance of visitors’ contextual activities. The main set of services includes the design and implementation of a web portal and the implementation of supporting infrastructures for the development of museum navigation applications using

mobile devices. In the web portal the visitors can learn more about the Museum, its exhibits and collections, as well as prepare their visit and to pre-organize educational activities. The navigation application allows visitors to explore the Museum assets with the use of a mobile device and to take part in educational activities, augmenting thus the experience within the museum. The selection of the digitized material was concluded in close cooperation with the personnel of Museum of Solomos and the total number of items exceeded 2.000.

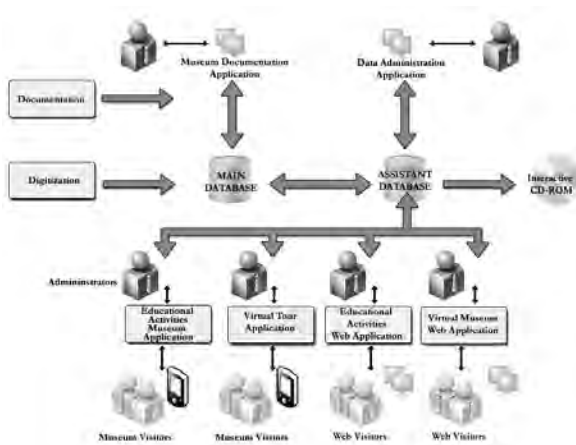


Figure 2: Application Study Architecture

The assistant database also stores the selected material used for the design of an interactive CD-ROM for the presentation of the museum. The main database stores the digitized surrogates and is linked with the Museum Documentation Application, which is supervised by the system administrators, while a second system administrator monitors the operation of the assistant database and handles the stored data (see Figure 2).

The whole system has been developed using a Php-MySQL platform. The main reasons for using this platform was its portability (can be used in most operating systems and servers) and its ease of implementation. It should also be noted that the platform does not require any special php libraries and all functionality is developed from scratch, thus making it more robust. The platform is modular and various modules have been developed for carrying out most of the tasks described in this paper. The functionality described in the previous sections is implemented in the following modules with the first module carrying most of the complexity:

- Item module: insert/edit item properties
- Group module: insert/edit item groups
- Person module: insert/edit person authorities
- Reports module: produce reports for the museum
- Settings module: administer system modules/users

Users access the system and to each module through the user management facilities of the platform which allow each user to be given specific access to each module. The platform also allows the export of the museum items to XML according to the CIDOC/CRM standard. Being an open source system, a skeleton module is also supplied along with a simple yet comprehensive development guide in order for the museum administrator to be able to add new functionalities to the system.

## 4.2 Challenges

The challenge for the development team was to provide a unified schema that would:

- conform to the metadata interoperability guidelines expressed by a set of Document Type Definitions (Kalomoirakis et. al., 2005), dictated by the project supervising authority (Information Society Secretariat, Greece), in order to augment linkage and information exchange with other collections that constitute the national cultural heritage digital inventory,
- ensure semantic relationship of similar items and thus supporting semantic interoperability as guided by the implementation of CIDOC/CRM (see Table 1) and
- preserve valuable information concern the museum wealth and enhance the effective information retrieval from the various access applications offered to local and remote users.

The museum material was described in printed storage forms of archival description, which were designed and provided to the Museum of Solomos from the Greek Ministry of Culture and most specifically from the Headship of Cultural Heritage (former Headship of Popular Culture). These printed forms represent the long-term tradition of recording museum exhibits and through the use of specific fields it is highlighted the significance of specific parts of museum information. Many of these fields are necessary ingredients of the museum metadata schema, which could not be ignored during its conduction.

The form included the following grouped information:

- *Identification and Description information:* This information were concerning the entry number or any other former identification number, the category of the item, the number of its constituent parts, quick description, local labeling and its authenticity characterization.
- *Manufacturing information:* Details about the spatial and temporal dimensions of its manufacturing, its author, materials and techniques needed, dimensions and weight.
- *Usage information:* Information that help replication of the aim and the context of use of a specific museum item. It refers to the spatial and temporal dimensions of use, the population using it and the way of usage.
- *Acquisition information:* Details about the way of acquisition from the Museum of Solomos. It refers to spatial and temporal information of acquisition, the way of acquisition, former possessors, value and formal documents proving its acquisition.
- *Free Text information:* Area of free text commenting and annotation of aspects of the item that could not enter in other fields.
- *Archival information:* This information was divided in sub-categories that referred to the archival folders of the forms, its current position and the aims of research that was conducted based on this item.

Despite the comprehensiveness of the form for the recording of each item, a synthetic approach is needed in order to achieve the convergence with the requested standards, which qualify syntactic and semantic interoperability. Furthermore the printed forms responded to needs of earlier time periods, where the conceptual approach was object oriented. However recent developments allow a directional shift by focusing on the event-

oriented replication of museum items. One specific example of this shift is the highlighting of the relationships between the items, which occur as a result of the contextual parameters. It is obvious that in a physical space, like the museum floors and halls, users maintain their own self-activity and they follow their own paths of exploration. Therefore supporting applications, like labeling or mobile peripheral access, the visitor should be self-sufficient to gather all data required for the whole view of the events, the concepts and the historic context in general. These semantic relationships allow the synthesis of the surrounding world of the item.

Field title	Creator_id
Definition	The name of creator (manufacturer, artist etc) of the museum item.
Sub-fields	-
Occurrence (Entry)	Optional
Occurrence (Multitude)	Multiple
Accordance with DTD	Manufacturer [person]
Accordance with CIDOC/CRM	E12 Production: P14 carried out by /performed: E39 Actor

Table 1. Instance of a mapping between the Digital Museum Management System database, DTD and CIDOC/CRM.

### 4.3 Mobile navigation

The Solomos Museum also features a mobile navigation subsystem which utilizes a Windows mobile PDA equipped with an RFID card reader and an application that offers to the visitors a number of services allowing them to:

- locate certain items and navigate to them from any location in the museum,
- view information about items and relate items with each other, and
- provide visitors (especially students) with educational applications (e.g. games).

DMMS supported this specific application, by supplying links between certain elements of the items' metadata and the mobile devices and by rendering the information for the proper presentation (e.g. small screen size). Details regarding the mobile application architectures, services and applications can be found in (Cabrera et al. 2005).

## 5. CONCLUSIONS

In conclusion, the design and implementation of a museum management system named Digital Museum Management System was presented in this paper (DMMS). DMMS consists of modules for storing information about the museum items and exporting some of this information (a) to the museum's portal (providing information to the online visitors) and (b) to the mobile devices (providing location services and educational functionalities). Apart from the complex design of the system, most metadata elements had to be mapped to the CIDOC/CRM ontology so that all knowledge inserted into the system is semantically annotated and interoperability with other similar applications is possible. DMMS is on continuous development by integrating new designing recommendations and by applying suggestions for further improvement.

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## A DYNAMIC WORKFLOW MANAGEMENT FRAMEWORK FOR DIGITAL HERITAGE AND TECHNOLOGY ENHANCED LEARNING

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**KEY WORDS:** Workflow Management Systems, e-Learning, e-Libraries, Web Services and Windows Workflow Foundation

### ABSTRACT:

Workflow management systems have become an integral part of most enterprise projects for the production of various tools concerning data and control flow management for more than a decade now. Despite the large number of workflow systems none have been applied to the digital heritage e-Learning domain. This paper represents an optimised solution for customising the architecture of workflows in order to improve productivity (effectiveness) in a service-oriented digital library and technology enhanced learning system. This paper presents the application of workflows to e-Learning and digital libraries within a dynamic workflow management framework. Our workflow solution is described and analysed by considering a typical use case scenario. Particular emphasis is placed on examining how the new workflow model can improve the speed and increase the efficiency of a digital library focused on e-Learning. Our service-oriented digital library architecture is demonstrated by integrating four main components using web services: 1) digital content creation, in for example 3D content creation, 2) archival, i.e. storage and management of this 3D content for use and re-use, 3) organisation of digital heritage content into an e-Learning exposition or package and 4) final presentation of this content that exploits innovative visualisation and interaction techniques based on social networking, which allows incorporation of user defined content in a virtual and augmented reality Web 2.0 mashup. Other technologies exploited in this scenario include a web service-based Grid solution for generating 3D animations from the 3D content.

### 1. INTRODUCTION

Workflow-based e-Learning systems are considered to be one of the most promising innovations that emerged over the course of the last few years fuelled by the proliferation of Internet technologies especially Web Services and Grid Computing. Such systems add a new dimension to traditional e-Learning systems because they incorporate a number of characteristics that make them highly effective, interactive, scalable, customisable and flexible. This can be seen clearly in a workflow-based e-Learning systems ability to utilise real-time workflow management, and other characteristics such as: dynamic generation of tasks, automated performance management, customised delivery of tasks and task support that make e-learning systems as effective and rich (Lin et al. 2001).

The nature of e-Learning systems make it possible to break their functionalities into business processes that can be easily managed by workflow management systems, making such an approach a logical step forward in this area, similarly it is possible to break digital library functionalities into a set of business processes that can be managed by a workflow management system. A digital heritage library manages, stores and uses digital heritage objects and resources that could be presented or interacted with in an e-learning environment. Therefore the implementation of a digital heritage library and technology enhanced learning system through careful integration of appropriate workflow management systems is bringing a whole new set of functionalities and interaction modes to existing e-Learning and digital library models.

Using workflow management within an e-Learning environment comes with its own challenges and considerations

due to the complexity of such systems and the need to manage their intersecting tasks. A number of factors should be taken into account when integrating workflow management in e-Learning systems; these include:

1. Modelling the e-Learning activities and processes.
2. Resource management across the system.
3. Customised contents for users.

In this paper a workflow solution for a typical use case scenario within our digital library and technology enhanced learning system [Patoli et al 2007] is presented, with particular emphasis placed on examining how new workflow models can improve the speed and increase the efficiency of a digital library focused on e-Learning. Typical digital or cultural heritage materials that our integrated digital heritage library and technology enhanced learning system seeks to handle are discussed extensively in the ARCO project [ARCO 2008], and can also be seen in the UK's Portable Antiquities Scheme [PAS 2008], while the overall architecture for our system is discussed in [Patoli et al 2007].

Our service-oriented digital library architecture is demonstrated by integrating four main components using web services:

1. Digital content creation, for example 3D content creation.
2. Archival, i.e. storage and management of the created content for use and re-use.
3. Organisation of digital heritage content into an e-learning exposition or package and final presentation of this content in an e-Learning presentation.
4. Presentation that exploits innovative visualisation and interaction techniques, based on social networking

that integrates user-defined content; using virtual and augmented reality in a Web 2.0 mashup.

In addition to integrating these four processes in a workflow management framework we also include activities typically found in GRID and Enterprise environments. Further, we exploit the Windows Workflow Foundation WF to implement our system.

This paper is structured as follows: formalization of the solution, framework implementation, results analysis and future development.

## 2. FORMALISATION OF THE SOLUTION

### 2.1 Workflow-enabled e-Learning Overview

E-Learning is a wide discipline that does not only cover the traditional classroom teaching and assessment but goes beyond that to provide extensive interactive services to learners in all areas of specialisation (Lin et al. 2001). Therefore, such systems can have complex processes that require good coordination between the system agents to ensure its sound operation. Modern e-Learning systems can be typically web-based where their services are delivered through a network infrastructure such as Grid Networks and the data delivery is handled through highly customisable techniques like the approach where a combination of data-enabling tools and web service-based mashups are used. One of the developments that accompanied the proliferation of e-Learning systems was the introduction of digital libraries which gave e-Learning systems a new wider dimension enabling them to have better means of data-enabling and distribution among users (Weining, Junzhou, and Tiantian 2005).

The operation of such web-based systems requires the use of multiple services that can be complex at times requiring effective mechanisms to manage and coordinate them. Workflow management paradigms can be utilised to arrive at a viable framework in which all the aspects of the e-Learning system can be effectively managed.

Figure 1 below gives an overview of the typical tasks which an e-Learning process performs to accomplish its required functionality. The starting point is the actual data acquisition, followed by data processing to recognisable formats that are stored in the archival services for later retrieval by the search processes that are requested by the system users.

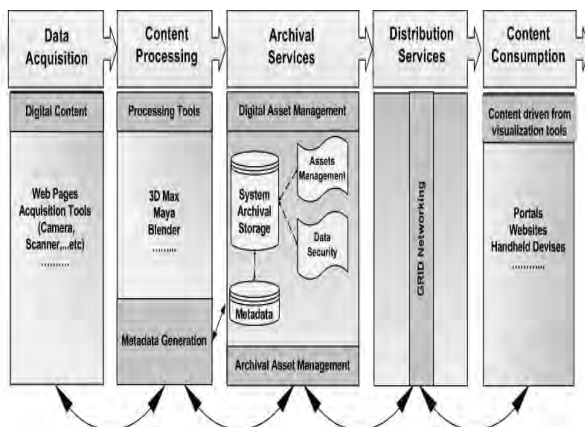


Figure 1: Typical services in an e-Learning environment

### 2.2 The Proposed Framework

The proposed solution is the result of the implementation of a workflow management framework prototype to be incorporated into e-Learning and the associated digital library systems. The chosen technology to implement the solution is Microsoft's Windows Workflow Foundation (WF), which offers great integration and flexibility features especially in conjunction with the use of web services (Mezquita 2006). The model will be broadly based on the backbone of web services where the different system tasks are accomplished through their public functions. The workflow management system will manage the use of these web services, coordinate the data transmission processes and manage the final delivery of the data to the user whether it be a picture, a sound clip or a 3D image to name a few of the objects that e-Learning and digital library systems may deal with. The web service-based architecture will enable the system to cope with the intersecting processes that are performed by the web services from one side and the system users from the other. Furthermore, as Grid computing is arguably one of the most efficient networking paradigms useful for e-learning—and we use a Grid based on Condor (Patoli et al 2008) to generate animation content—our proposed workflow management solution will operate on top of our Condor Grid computing infrastructure. Figure 2 below illustrates the main operational elements of the workflow framework.

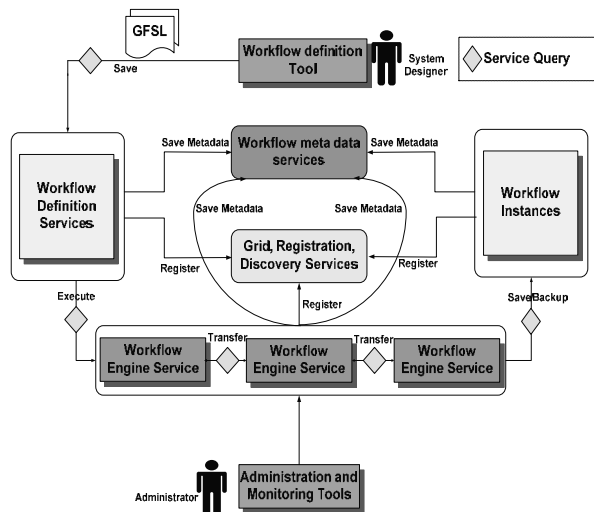


Figure 2: Operational elements of the workflow framework

This workflow framework can be seen as a controlling mechanism where all the system processes are orchestrated in a consistent manner in a well-defined workflow operational model.

### 2.3 Workflow Model

The core component of the proposed framework is the Windows .NET workflow runtime services that form the operational cores of the WF. According to (Paventhana et al 2006) the above-mentioned component is “responsible for the execution, tracking, coordination and scheduling of the required services”. The actual workflow engine requires hosting services to host its operation and provide various functionalities among which communication and threading services are the most important (Chappell 2005). By exploiting this flexible approach, all the functionality of the e-Learning system can be

hosted within the WF that can operate on top of the existing GRID environment. The produced workflow system will basically be constructed from the following components:

1. The WF activities and services.
2. A GRID access to the system resources.
3. System activities for data acquisition, creation, processing, exposition, visualisation and interaction.
4. Database activities for data storage and retrieval mechanisms.

The WF supports three types of workflow models which are Sequential workflows, State-Machine workflows, and Rules-Driven workflows. According to (Chappell 2005) sequential workflows are used for applications where the workflow's activities are executed in some sequence, whilst a state-machine workflow organises its activities into some kind of a fixed state machine. The rules-driven workflow model operates by following a set of pre-defined rules that drive the processing order of the workflow being followed.

Currently we are exploring sequential workflows for simplicity, however rules-based workflows present interesting challenges for building more complex systems that may better suit required functionalities for more personalised e-Learning with a digital heritage library. We also consider that all events are encoded within the workflow itself. Such a model allows the developer to execute a workflow bath that might branch or loop using the activities, rules and conditions that are per-defined at the development and coding stage (Allen 2006). The programming model in the WF is used to create the operational model where the workflow, and the different system rules and conditions are defined to manage the sequential operation of the workflow from its starting point to the point where it terminates as illustrated in Figure 2.

#### 2.4. Workflow Activities

The operation of the system is based on a set of workflow activities, for the e-Learning system that can manage its overall complex functionality, intersecting at different times. Such activities can be divided into phases that are outlined as follows:

1. System workflow modelling: Using standard modelling techniques regardless of the implementation framework in use to create an abstract model for the whole system.
2. Process specification: Where all the system processes are defined using a standard framework such as BPEL\* and XPDL\*\*.
3. Deployment: This involves the deployment of the implemented processes into their allocated hosts.
4. Execution: this involves the execution of the deployed services.
5. Administration and Monitoring: These are customised tools to monitor the performance of the executed services.

\* Business Process Execution Language

\*\* Process Definition Language

### 3. FRAMEWORK IMPLEMENTATION

#### 3.1. Exploiting the Extensible Model of WF

The adopted Service-Oriented Architecture (SOA) builds on an active Business Logic Layer that uses the key technology of the WF. Based on that, the future system implementation will exploit the extensible model of the WF allowing for the addition and creation of custom activities to achieve the desired workflow functionality. This model will consist of a number of services that constitute the overall architectural and management backbone of the system. In the extensible model illustrated in Figure 3 the persistence services perform the tasks of storing and retrieving instance state. On the other hand, the tracking services manage the system profiles. The scheduling and transaction services provide the resource for managing threading and creating the system transactions.

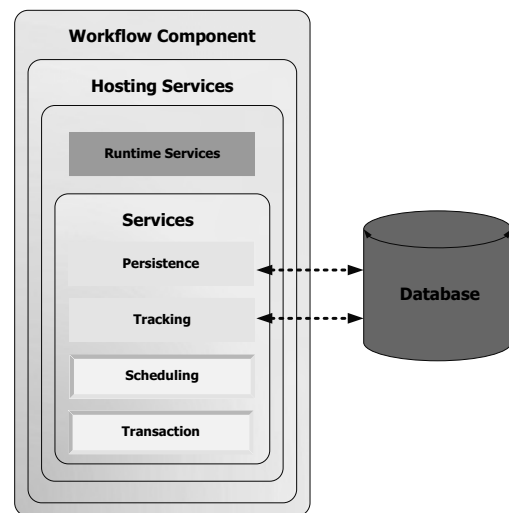


Figure 3: The Extensible Model

#### 3.2. Workflow Implementation Outline

The use of the WF for management and coordination of the workflows of a typical e-Learning and digital library environment shall start with the creation of specialised web services, which will be managed by the workflow framework. This is necessary because we aim to develop a flexible system that is based on SOA where the majority of the required system and user functionality is performed through the implemented web services. Such services are then managed through the customised workflow activities with the following main functions:

1. Database connectivity: This is achieved through a function to connect to the local or remote archival services.
2. Object management: This includes the addition of new objects and the editing and modification of the existing ones.
3. Object search: This specialised function performs the process of locating the required objects that are stored in the archival services that are represented in a data repository such as an SQL or Oracle database.
4. Object retrieval: This function retrieves the data objects that are requested by the user.



A sample archival services layer was also created to manage data objects, such as images, 3D files and sound clips. The core workflow engine is responsible for the execution of a number of tasks to ensure that the system is fully functional by providing effective means of management, tracking and threading of the used services. The core workflow functionality areas of the workflow framework are:

1. Start a process: This is when the actual workflow process starts.
2. Query system process: This service is used to query a specific process such as its current status and so on.
3. Invoke web service: To invoke the web services that are used in the system to perform certain tasks such as locating and displaying a data object.

**3.2. Practical Implementation of the Framework**

The system implementation is based on a typical use case scenario: its operation is dependent on the designed web services and the overall workflow services that are built on top of the WF in an environment that simulates a simple e-Learning application as will be illustrated below.

**3.2.1. Scenario**

The implemented framework was based on a simple scenario whereby a user requests a data object from the system’s archival services, the system locates the item and returns it to the user to be displayed using the appropriate visualisation tools. Requests from the user’s front-end are processed by passing the search string to the web service responsible for data access. If an object is found, it is directly transferred to the user’s front-end in binary format to be displayed there, otherwise an error message is displayed and the process is terminated as illustrated in Figure 4 below.

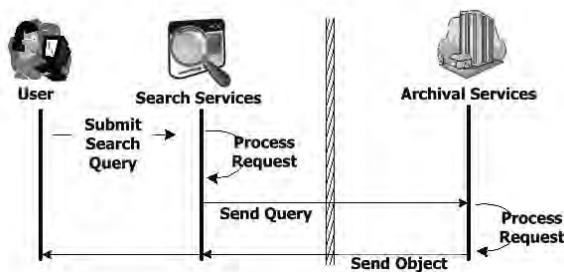


Figure 4 : Typical User Scenario

**3.2.2. Practical Implementation**

The produced web services will be used by the implemented workflow framework that is built on top of the hosting services provided by the WF. It is worth pointing out here that the separation between the business process and the actual implementation enables a smooth implementation of the SOA-based system. A sequential workflow was created to manage the different aspects of the above-mentioned scenario. In this respect an initial state and a completed state for the application were created to allow for the proper run-time management of the system workflow.

The business logic and the actual workflow implementation are all written in VB.NET, one of the standard implementation languages in the .Net Framework. A new workflow was created and web references for the two main web services were added so that their invocation and operation can be managed from the system. Then, the underlying workflow activities were added by using two major components of the framework which are the standard ‘ifElse’ branching to handle the different conditions of the system and the executable code activities that accompany the different events that the workflow encounters. For example, in our application the workflow rules are referenced as an XMLNS schema (XML namespace) as can be seen in the sample code extraction below:

```

<RuleDefinitions.Conditions>
  <RuleExpressionCondition
    Name="ifObjectFound">
    <RuleExpressionCondition.Expression>
  
```

Figure 5 illustrates the system implementation from a technical point of view.

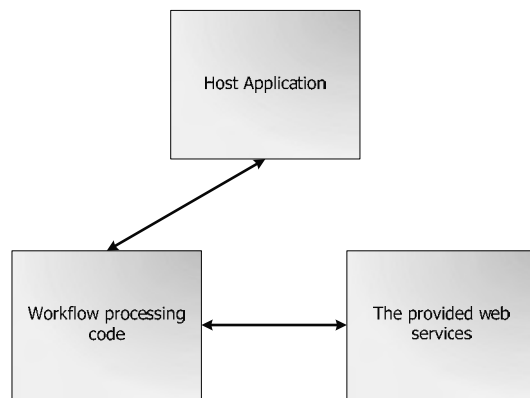


Figure 5: System Components

Executable code components were added for the following events:

Executable Code	Purpose
captureSearchString	Handles the submission of the user search string.
afterObjectRetrieval	Handles the object retrieved by using the concerned web service.
objectNotFound	Handles the event in which the required object was not found.

Table 1. Workflow activities

Each event was coded within the workflow to handle the different system events for example the submission of the event in which the object being looked for is found is invoked by the workflow itself by having the appropriate code handlers as follows:

```

Me.afterObjectRetrieval = New
System.Workflow.Activities.CodeActivity
Me.invokeObjectRetrieval = New
System.Workflow.Activities.InvokeWebServiceActiv
ity
  
```

A host project was created to host the workflow and this was achieved by the incorporation of simple host application within the framework. The actual design of the workflow was created by using the visual design elements provided in the WF that allowed for the required elements to be dragged and dropped into the workflow design area and then edited. In regards to task scheduling, the designer resorted to using the built-in scheduler services as they met the required tasks to drive the workflow execution. According to (Mezquita 2006), the 'DefaultWorkflowSchedulerService' takes the task of queuing the workflow items into a local queue before handing over the execution to the fully managed thread pool. As this service satisfies the underlying system needs the 'ManualWorkflowSchedulerService' was not considered. The overall workflow design can be seen in Figure 6 below.

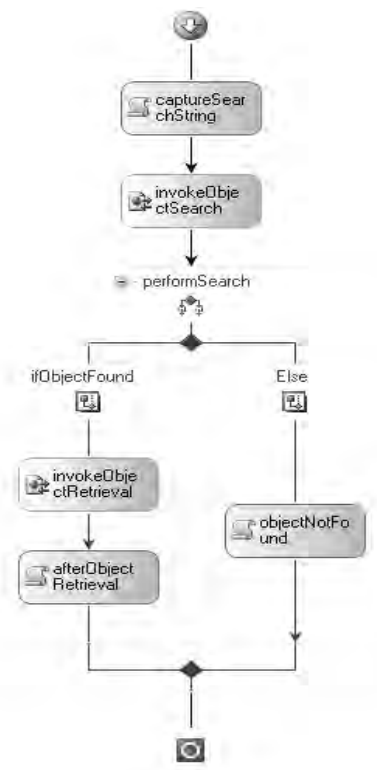


Figure 6: Workflow Design

## 4. RESULTS ANALYSIS

### 4.1 System Testing Plan

The operation of the system is managed by the workflow created in the WF and its host application. In the sample scenario a user requests a photo from the archival services to simulate a simple operation of a digital library system. The results of the implementation were verified by testing each build in all system iterations any defective workflow builds were corrected at the time of testing.

This simple operation in the sample scenario was tested in terms of the following criteria:

1. Execution of the actual workflows.
2. Web service calling and consumption.

3. The implementation of the workflow rules for example following the defined conditions of the 'ifElse' branches and the execution of the executable code units.
4. Overall speed and optimisation for example in terms of database connectivity, data retrieval, feedback and handling user input.

## 4.2 Conclusion

The use case scenario was run successfully on the underlying workflow infrastructure while maintaining good levels of scheduling, threading and data integrity. The WF provided a consistent model where all the services were hosted and managed efficiently while optimising processing times and data transmission mechanism. At this stage of our research, a major concern was the approach by which the WF can be utilised to accommodate the sequential operation of the digital library system within an e-Learning environment. The adoption of an SOA approach also proved to be a success where the invocation and consumption of the assigned web services led to the sound operation of the system. A key point that can be seen here is the ability of the produced model to be customised and extended to meet the changing functionality of such systems by exploiting the extensible model of the WF. As can be seen below, future work will accommodate more complex workflows while handling a more varied data types and user/application interactions.

## 5. FUTURE DEVELOPMENT

The scenario presented—the request of an object from the digital heritage technology enhanced learning environment—is only one of many use case scenarios that could be expected for a complete fully functioning system. For example, workflows for the creation of the object itself, the archiving process, consumption of the object(s) in different e-learning models, presentation of object(s) in a social networking environment, and many, many other workflows have yet to be developed. In addition, we need to decide carefully which e-learning models are best suited to the study of digital heritage and embed these models within the third main component of the system, i.e. the exposition component [Patoli et al 2007]. This will require an analysis of existing e-learning systems to determine their strengths and weaknesses to see which models are best applied to a digital library based system.

Thus, future work will focus on enabling the system to operate within more complex environments requiring many more complex and varied workflows where more varied data types and objects are processed and delivered to different e-learning environments. The integration and scalability of the framework will also be fully considered in the future development that will build upon this paper's research and findings. Other considerations will also include some additional functionality to accommodate the dynamic and varied nature of e-Learning systems, for example, multi-lingual interfaces.

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# **Image Analysis**



## EXTRACTION OF NUMERIC DATA FROM MULTILINGUAL ARCHAEOLOGICAL PAPERS

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**KEY WORDS:** Machine Learning, Information Retrieval, Named Entity Recognition, archeology

### ABSTRACT:

Over the last ten years, Named Entity Recognition (NER) has been successfully applied to extract data such as proper names, chronological data and locations from texts. NER often uses a technique called 'Memory Based Learning' and this implies the existence of a database with examples from the underlying language and domain, possibly augmented with handcrafted rules, to recognize new instances. We have used such techniques successfully for indexing scanned documents from the archives of the dutch archeological central office on chronological and geographical data. In many cases, however, these documents do not contain single papers, but complete issues of archeological journals and therefore include english, german and french papers, mixed with dutch texts and articles. One of the problems therefore is whether to separate examples and rules for every language, or to combine the examples in a large example base. We report on the system used for indexing chronological and geographical data, and describe the problems and advantages of both methods.

### 1. INTRODUCTION

In Cultural Heritage, as in most other fields of human endeavour, most knowledge is stored in the form of papers, articles, books and other textual repositories. In the computer age many of these texts start their life as a digital file and are archived in digital libraries, but there is a gigantic amount of books, reports and other texts from the pre-computer age that still do contain valid knowledge (and even if this knowledge is not valid any more in a particular domain, it still may be important to historians for a number of reasons). Institutions are scanning and OCR-ing these documents, creating a large amount of machine readable texts.

The selection of 'interesting' documents from a database with documents is called Information retrieval (IR). IR traditionally depends on the assignment of keywords; in the computer age this has come to mean the recognition and selection of words occurring in the text itself (derived indexing). However, such keywords have no semantic content: the system cannot see the difference between a 'bow' as a weapon and as the front end of a ship. In the case of numbers or locations this is even more problematic: 1492 can be a year, a dimension, a price in Euros, a number in a computation, or even the title of a movie; London can be a city or the name of a person. It is obvious that the recognition of years, locations and other semantic classes in documents is of importance for archaeologists and historians.

Much touted solutions for the acquisition of this knowledge are ontologies or even the Semantic web. Many AI scientists maintain that the world is like an airplane, only bigger, and that when you can unambiguously describe and relate all the parts that go into a Boeing 747, you can with some effort do the same for all fields of scientific and scholarly endeavour. This of course is a fallacy. Even if it were possible to describe the world in this way, we still have to contend with the writings of authors who had and have not such an all-encompassing and unequivocal view of the world, who use conflicting typologies, who may have made mistakes, suffer from inconsequencies of view, in short all the fascinating stuff that makes up history.

And before all, it does not solve the problem of 'relevance': a key factor in computing the performance of an IR system.

In (Paijmans/Wubben, 2007) we have described a method to recognize and index chronological expressions in natural language documents in the archaeological domain. This method used a database with examples from the dutch language, supplemented with some heuristics and a list of chronological phrases in the dutch language, such as the dutch equivalents of 'Iron age' or 'second world war'. We have opted for a new system, because existing systems, such as GATE (Cunningham,2005) are very much research tools, sophisticated and complete, but relatively slow and difficult to handle.

During the last half century the preferred language of scholarly and scientific texts has shifted away from the native language of the author and the 'traditional' scholarly languages towards english. Conversely this means that older document collections will increasingly contain articles in other languages. This is in itself no great problem if every paper or article has a file of its own, but in reality we find many documents, such as scanned journals, that combine many individual papers in two or three different languages in a single PDF document. It is not always trivial to separate such papers automatically and store them in individual files. Also, in those backward times, scholars as a matter of course could read two or three different languages and often inserted extended citations in those languages in their texts. We have redesigned our system to work with documents that contain both dutch, english and mixed dutch/english documents. Other languages can easily be added, given a database with examples, a parser to recognize cardinals and ordinals and a few more heuristics for every new language.

In this paper we will describe the current status of the Open Boek project, a system for Named Entity Recognition in the archaeological domain, more in particular the different strategies we used to recognize and index chronological expressions (henceforth 'chronex') and geographical names ('localex') in documents that span several languages. The system is Open Source and can be downloaded and used under

the conditions of the GPL. It is written using the LAMP framework (Linux, Apache, Mysql and PHP). Therefore to create the indexes, a Linux system is needed, but the retrieval engine is designed to run under other operating systems as well. In any case, administration and querying of the contents is done by browser and therefore can be done from any platform with a suitable browser.

## 2. THE DOCUMENTS

An important constraint is the format of the digital documents. At the RACM,\* we have access to large collections of thousands of reports in all kinds of formats. They can largely be classified in three groups, which we will discuss below.

1. One group of documents (about two thousand reports of approx. fifty pages each) were originally typed on paper, and later scanned, OCR-red and stored as PDF. In such files, the 'image' of every page was paired by an 'invisible' ASCII text that could be easily extracted and indexed. There are some problems and caveats here. Sometimes, the lay-out of the pages is in two columns. As we will see later, Open Boek concatenates all lines on a page and slides a text window of ten words over it to find *chronexes* in context. The correct concatenation of text lines in columns of OCR-red texts does not always work, and the coherence of the text is disturbed. The effect on the precision however was negligible.

2. Another large portion of the files was already written using a word-processor and stored as PDF. Unlike the first group, there was no OCR step necessary, and the quality of the text was much better. Such files translated relatively easy in HTML, combining highlighting, links and images. Text in columns also is correctly aligned.

3. A third group of documents consists of hundreds of reports written by individual archaeological bureaus and made available on CD. These were almost always produced using Microsoft software. Without a doubt every CD contains a highly artistic multimedia feast with sounds, movies and everything, but it was absolutely impossible to extract the original reports without a time-consuming process of analyzing the contents of every CD by hand, defeating the purpose of *automated* indexing and retrieval. But even if the 'central' document could be identified, Microsoft's OLE framework essentially prevents precise extraction of the relevant data, at least with the tools that we used. Also we often find otherwise invisible pictures or phrases in the Word documents that obviously are not meant for publication and are included without the author being aware of it. To avoid all these problems MS-Office documents have to be converted to PDF before Open Boek will process them.

So we decided only to accept the PDF format for input, although HTML and ASCII txt-files are also accepted under certain conditions.

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\* The RACM (for Rijksdienst voor Archeologie, Cultuurlandschappen en Monumentenzorg) is the dutch central office for cultural heritage

## 3. DESIGN OF OPEN BOEK

Open Boek is designed for the indexing of up to 100,000 pages of text. The complete conversion from pdf to txt, and subsequent indexing on keywords, chronology and place names then will take a week on average computers.

The first decision we had to make was on the scope or granularity of the indexing system: document, page or some logical unit such as chapter or paragraph. As the format of the files to be indexed was pdf, and pdf is essentially the image of a document as printed on paper, we decided to take the page rather than a logical unit. Using pages theoretically could break *chronexes*, where e.g., '12th' ended one page and 'century' started the next one, but so far this was not observed even a single time.

Then there was the question what to do with artefacts in the text: footnotes, tables, illustrations and similar constructs. Obviously such artefacts have consequences for the semantics of a word or phrase, but in OCR-red text they are difficult to identify and PDF is not really suited for logical text descriptions. Therefore we ignored the difference between such artefacts and running text, essentially using every page as a 'bag of words'; a concept that is very common in IR.

Every pdf document (see figure 1, top) is first converted to as many HTML files as it contains pages. The tags and the text are then separated and stored in separate files. This 'stand-off' representation (Dipper:2005) has the advance that new files with mark-ups for e.g., the chronological expressions or geographical information can be added without disturbing existing structures. It also makes it easy to render the pages with tags for selected features.

At this point, the system also decides on the language of the individual page (at this moment dutch, english, german or french).

In the final document representation all text, regardless of status, is then concatenated from left to right and from top to bottom in the order that it appears in the HTML page. This page then is used for the collection of candidate *chronexes* and *localxexes* (chunks of context with a numerical expression, or with words that are potential place names).

Apart from the recognition of chronological and geographical data, a retrieval system should incorporate some strategy for selecting keywords. We used the venerable SMART system, that despite its age still performs well in the TREC publications (Buckley-2005). All word types (except for a 500 word stoplist) are indexed and weighted with a *tf.idf* variant (Salton-1983). At retrieval time, different strategies are offered to the user to combine the words, use truncation or display a KWIC index.

### 3.1 MBL: general

Memory Based Learning (MBL) essentially consists of the collection of a large database (10,000-15,000 lines) with positive and negative examples of the class that should be recognized. These examples then are classified by an expert. This is the example database. At processing time a list with new candidates is collected from the texts. This list then is compared with the example database. For the MBL part, we used TiMBL 5.1 (Daelemans et al., 2004) a decision-tree-based implementation of k-nearest neighbour classification or KNN. KNN classification is a method of classifying objects based on

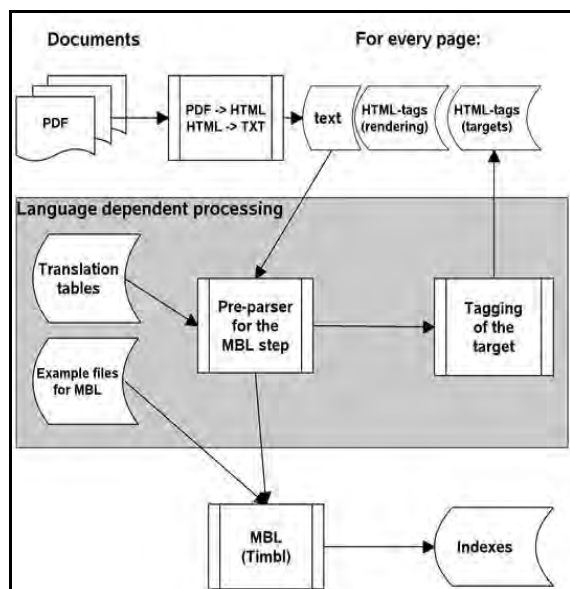


Figure 1: Indexing chronexes and localexes in Open Book

the closest training examples mapped in the feature space (see figure 1, lower center).

For the chronological indexing, an additional list of expressions such as 'middle ages' or 'second world war' is consulted, and the proper chronology is added to those expressions. We will call this list a translation list. For geographical indexing similar translation lists exist (see below).

### 3.2 Chronological indexing

As our goal was an application for creating indexes, we have not sought to reproduce the finer distinctions of the timexes (time expressions) of (Ahn et al., 2007). This implies that we made no effort to recognize and compute relative time expressions such as 'yesterday' or 'next year', but instead concentrated on unambiguous dates.

The preparser (refer to figure 1, in shaded rectangle) first selects tokens, that are numbers, cardinals or ordinals. It takes then four words in front of the token and four after it, and adds it to the list of candidate chronexes. Cardinals and ordinals are translated to integers, taking account of chronological multipliers like 'century'. This list is fed to the MBL program, that recognizes those numbers that are part of a chronological expression. The chronexes are then translated into a start date and an end date in the yyyyymmdd format (negative for dates

- 500, 501, 502,... 1599, 1600
- between 1200 and 1300
- twelfth century
- 12 <sup>th</sup> century
- + XII
- hundred years war
- medieval

Table1: Examples of chronological data returned for the query '500-1600'

before Christ), even if they only contain a single day. Smaller units are not recognized. Names fore chronological eras (middle ages or pleistocene) are looked up directly in a list (the translation table).

After processing, we have a SQL table that for every page and every document records the chronexes that occur on that page. At query time the user enters a single expression ('middle ages'), that is then translated in a period, or he enters a period of time e.g. 500BC-500. The query is then compared with the index and by default the chronexes that are contained inside the user supplied chronex are returned .

An example (see table 1): if the query would be 500-1600, and if the middle ages are defined as 500-1500, every mention of the middle ages would count as a hit, as would every year, century or other period of time between 500 and 1600 inclusive. If the hundred years war (1373-1457) or 'medieval' were entered in the translation table, those events would also be included. However, the dutch war of independence (from 1568 till 1648) would not be contained inside the query and would not be returned. Of course there are options to change this behaviour, so that every chronex that overlaps the query partially is also returned.

As an extra module, although not part of the indexing proper, we added a tagger, that added stand-off files with HTML tags to the chronological expressions, so that at retrieval time they would light up in the rendered page.

### 3.3 Geographical indexing

The recognition of names of villages and towns needs the MBL stage in the first place to differ between references to the location proper, and the same words in surnames of persons or even as part of the name of an institution. 'The city of Londen' is a geographical location: 'Jack London' or even 'The bank of Amsterdam' is not. It also tries to differ between the mention of a place as location proper and as a part of a bibliographical entry.

For the selection of candidate localexes, we used the freely obtainable database of geonames<sup>\*</sup> and applied some of the heuristics from (Pouliquen et al., 2006). The modus operandi was as follows:

All capitalized words are checked to the geonames database. If only one match is found, this match goes directly to the MBL list with candidates.

If the name has more than one entry in the geonames database, which is the regular case, a disambiguation algorithm is called. This algorithm computes a score for the probability of a place being the correct choice on six points:

1. Is the country of the candidate the default country
2. Is the country the same as the country of the last identified place.
3. Is the country mentioned within a certain distance of the place in the text
4. The distance of the candidate to the last place identified
5. The number of inhabitants.
6. Whether the place name has as feature 'populated area'.

\* <http://www.geonames.com>



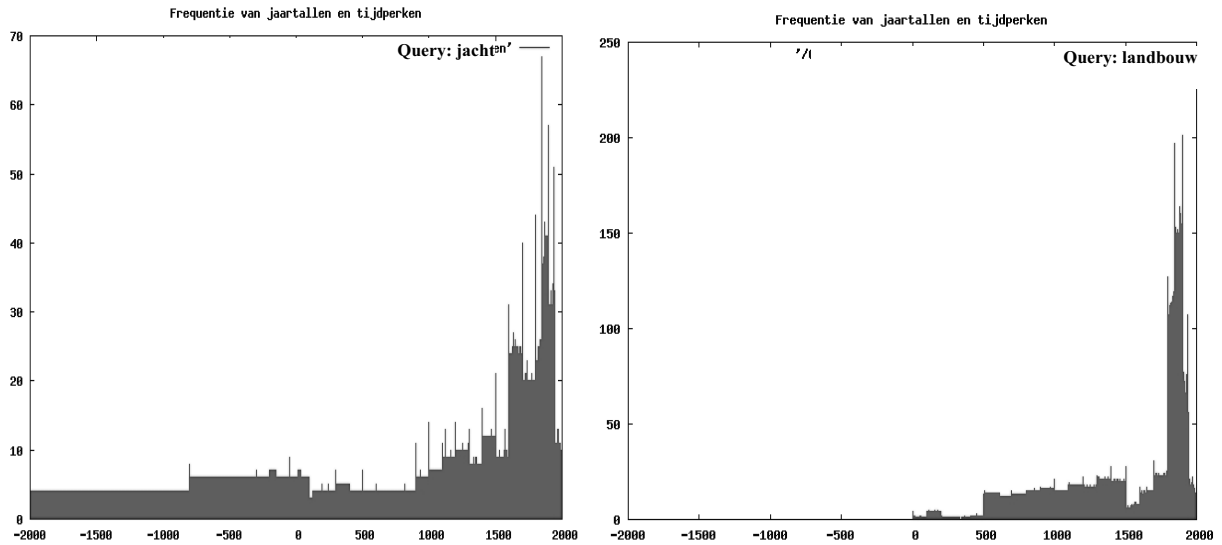


Figure 2: Co-occurrence of hunting (left) and agriculture (right) with chronological expressions. Note the different scales on the vertical axis.

All these points are weighted and added to the score of the candidate; the winner then is added to the MBL list. Then MBL is used to separate the real place names from names of persons or institutions.

The translation tables here have a twofold function: first they offer translations and alternatives for the place names: Paris and Berlin in dutch are written 'Parijs' and 'Berlijn'; the city of 's Gravenhage is also written 'sGravenhage, 's-Gravenhage or most frequently 'Den Haag'. Although the geonames database has a field for alternative names, it is not efficient to search the table on that field. Finally, the system needs the names of the countries and their derivatives in that particular language for step 3.

Pouliquen also uses Part of Speech (POS) tagging to select candidate placenames, limiting themselves to nouns. We have found that for the dutch situation at least, the results were negligible, or even disadvantageous, and that the time that was needed for the POS-tagging therefore was not worth it. Of course there are other linguistic tasks that may need a POS tagging of the material, and we have included the possibility in the system on the basis of Mbt (Memory based tagger, a derivate of Timbl).

The indexes proper again are stored as SQL tables; stand-off tagfiles are added with corresponding markups such as the Googlemaps entry for locations. The data that are stored for the localex or geographical names, are the name of the place, the country and the geographical coordinates. Finally we also added HTML tags for highlighting at retrieval time.

We will conclude this section with a small demonstration of the information that can be gleaned from the reports if and when the chronological information is made explicit. Open Boek offers the opportunity of creating a histogram of the chronological expressions on pages that are returned as the result of any query (but note that the relation is just that of co-occurrence on the pages). In the example we submitted two queries, 'hunting', and 'agriculture', to a collection of papers on the history of dutch towns and villages (750 documents with 30,000 pages, totalling 1.7 Gigabyte of PDF documens). The

corresponding graphs are those in fig 1, but note the different scales, caused by the fact that 'hunting' occurs on 32 pages, whereas 'agriculture' occurs on 913 pages.

A few interesting features are visible from left to right. First, note the plateau caused by frequent references to the 'Iron age' defined as between 800 BC and 50 BC in the graph on hunting, left. The spikes in the graph are caused by the human tendency to gravitate to 'round' numbers. This is very visible in the years 500 AD and 1000 AD and to a lesser degree every 100 years. The surge towards the nineteenth century in both graphs should be explained as the result of the increasing activity in the townships and villages of the Netherlands, and therefore dates in that interval occur much more than earlier dates. Of course these raw data need more processing to draw conclusions from, but it points the way to methods of text mining in full-text archeological publications.

#### 4. LANGUAGE DEPENDENT INDEXING

If we consider the various modules in Open Boek, there are three places where the language is a factor in processing. Those are the translation tables (the supporting tables for chronological eras and locations), the labeled example files for MBL and the parsers that extract candidate chronexes or localexes. All these items are grouped inside the shaded area of figure 1.

It should be noted that the translation tables generally are not actually dependent so much on the language, as on the nationality or even the domain that is covered in the document: a document in the english language may well contain references to Australian or Chinese geographical locations; if a dutch paper mentions the Iron age in Greece, it has quite different boundaries from the same era in Holland. For the english world the second world war is 1939-1945; but in the dutch context it is as often 1940-1945 and so on.

On the other hand, the example files for MBL and disambiguation are language dependent because they mainly

depend on linguistic context (although the domain also is important for correct recognition of named entities). This is true for the database with examples, but also for the parsers that extract candidate chronexes, and that after recognition of a chronex, translate it to its canonical form and tag it for display.

#### 4.1 The MBL databases

As we have seen, the documents are indexed by page. Therefore it is easy in mixed language documents to automatically decide the language for every individual page and to select the correct MBL database.

The alternative is to omit language detection and concatenate all example databases for every language. There are two drawbacks to this method: first that the parameters of the MBL program cannot be tweaked for the individual language, and second that processing lasts much longer, because all examples must be compared (and as the number of supported languages increases, the database increases correspondingly). Therefore we have opted for the first solution and at indexing time the correct example database is automatically selected. At worst this leads to a slight decrease in accuracy when on a page long phrases in a different language are used.

The recognition of chronological expressions in dutch texts has a precision of about 95%; in english texts it is at the moment somewhat lower (88%), possibly because the scoring of the example files was not done by a native speaker of the english language.

#### 4.2 The translation tables

As we have said above, the translation tables are not only dependent on the language proper of the document, but also on the *domain* of the document. This complicates the correct translation of the items. 'Bronze age' in the context of settlements in Greece is different from that in England, even if both documents are written in English. This means that for every context, different meta-information files should be present and that the system should be able to decide which meta-information is suitable on a given page.

Mutatis mutandis, the same is true for disambiguation of geographical names: there are at least twenty villages and towns all over the world with the name Amsterdam. To identify the place that is mentioned in the text, the system should have translation tables to at least be able to recognize references to countries in the context and alternative names of cities (German Mailand is Italian Milano or dutch Milaan).

We are currently experimenting with sets of rules that try to establish the chronological (or geographical) context of a given document, based on the recognition of cue words or even on the authority of the author herself. Some phrases, such as '*in the iron age (800BC-100BC)*' can be recognized and the option is to override the translation table for that era for the rest of the document. Such options should be exercised with caution because a known default will be exchanged for an unknown quantity, and we found that it is not at all easy to find the place where the default should be restored. Of course, the administrator of the database can pair specific meta-information files with individual documents, or even pages, by hand but this would defeat the goals of automatic interpretation and indexing.

This also adds complications for the queries. If the user puts a query 'Iron age', it is already uncertain whether he uses the same interval as that in the translation table. If more than one translation table is used for the interpretation of the documents, it is unclear which table should be used to interpret the query and then a term like 'Iron age' can be very imprecise indeed. The best solution is to use only absolute years ('800BC-100BC' instead of 'Iron age') in queries.

#### 4.3 Adding new languages

Adding a new western language, e.g. german or spanish, to the MBL-system is relatively easy. A new parser for the language has to be written, that converts cardinals and ordinals in the text to integers and creates lists with candidate chronological expressions. Such parsers often are in the public domain or Open Source, and are easily adapted to the system. Secondly a database with examples has to be created (typically 10,000 to 15,000 lines) and classified by hand (less than a day for a native speaker), after which the system is ready to detect chronexes in the new language. Also, a list with the names of chronological eras for that language should be prepared to translate e.g. Mittelalter in 500-1500. The same is true for the localexes: new languages need new translations for cities and countries.

A third module can be written to recognize sensible boundaries in the text to emphasize the retrieved chronex in the text. For the extraction of localexes similar preparations apply.

The situation for non-western languages is more complicated. Open Boek has no special provisions for Unicode, although the computerlanguages that were used, do support it. We have not pursued this avenue of research.

## 5. CONCLUSIONS

Information Retrieval is a continuous confrontation with the fact that perfection is impossible. This is not only caused by semantic confusion, but also by the fact that the key notion of 'relevance' is impossible to define or quantify. Yet, AI is slowly capturing at least some of the semantic information needed to query the content of a document instead of only meaningless strings. It is in our view pointless to wait for perfect precision and recall: it is the very essence of IR that this is not possible. Nevertheless relatively simple classes as chronology and geography can be developed to the point that they can be confidently used in searching the documents.

We have designed a system that will retrieve those pages that contain specific chronological and geographical information in at least dutch and english documents in the historical and archaeological domain. It was found that the system performed best when the example files for MBL-based recognition of chronological expressions were kept separated, and that the domain-dependent meta-information should be preferably kept to default values. Although this in itself is not new, we have developed the system to the point that it can be used 'out of the box' in every context that contains pdf or html documents and have made it freely available for download and evaluation.

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## VIDEO ACTIVE – EUROPEAN TELEVISION HERITAGE ONLINE

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**KEY WORDS:** Semantic Web, European Digital Library, Audiovisual Archives, Streaming media, Asset Management, Open Archives Initiative.

### ABSTRACT:

This paper provides an insight into the background and development of the Video Active Portal ([www.videoactive.eu](http://www.videoactive.eu)) which offers access to television heritage material from 14 archives across Europe. The Video Active project, a content enrichment project under the eContentPlus programme, has used the latest advances of the Semantic Web technologies in order to provide expressive representation of the metadata, mapping heterogeneous metadata schema in the common Video Active schema, and advances query services. Using these technologies, Video Active is fully compliant with the EDL interoperability specifications.

### 1. INTRODUCTION

The greatest promise of the internet as a public knowledge repository is to create seamless access for anyone, anywhere, to all knowledge and cultural products ever produced by mankind. Mainly due to increased bandwidth availability, web sites offering online video material have managed to mature and in a short period have become extremely popular. Web sites like YouTube, MySpace, Revver and many others show how the idea of making and manipulating images (once mostly the preserve of professionals) has been embraced as a way of broadcasting who we are to anyone prepared to watch. The most popular site to date, YouTube, was launched in early 2005 and serves over 100 million video's daily (Viracona 2007). The number of user generated video uploads per day is expected to go from 500,000 in 2007 to 4,800,000 in 2011 (Ireland 2007). Recent studies indicate that the number of U.S. internet users who have visited a video-sharing site increased by 45% in 2007, and the daily traffic to such sites has doubled (Rainie 2007).

Looking at these numbers, it's evident that the potential for releasing material from audiovisual archives online is enormous. To date, however, from the many millions of hours in these archives online a few percent can be found online. (Wright 2007) Many of the existing online services are based on user generated content. And if professional content is offered (i.e. Joost, Miro, Blinkx) the focus is rather on recent material. Audiovisual archives need to overcome several obstacles before they can set up meaningful online services. These include: managing intellectual property rights, technological issues concerning digitisation and metadata standardisation and issues related to the way the sources are presented to users. The latter is even more challenging if the aim is to present material from several countries in a structured way, in fact the starting point of the Video Active project.

The main challenge of Video Active is to remove the main barriers listed above in order to create multilingual access to Europe's television heritage. Video Active achieves this by selecting a balanced collection of television archive content, which reflects the cultural and historical similarities and

differences of television from across the European Union, and by complementing this archive content with well-defined contextual metadata. Video Active is invited member of EDLnet, the network was initiated in 2006 to build consensus to create the European Digital Library\* Video active will be made available though the Europeana.eu portal.

This article firstly introduces the main challenges and in the second part will provide some details on the technical infrastructure that was created in the first and second year of this three-year project. Finally, screen shots are included that show the design of the Video Active portal.

### 2. USERS AND THEIR NEEDS

Video Active is funded within the eContentplus programme of the European Commission (Content Enrichment Action) and started in September 2006 for a duration of 36 months. The first beta version of the portal was launched in February 2008.

14 Major European audiovisual archives, academic partners and ICT developers form the consortium. The archives will supply their digital content; the universities are the link to end-users and play an important role in developing a strategy for selecting the content and in delivering the necessary context information. Added up, their collections comprise of five hours of audio and video material from 1890 up to today.

Amsterdam based Noterik B.V. is specialised in online video solutions and responsible for the development of the Video Active portal application. The second technical partner is the National Technical University of Athens, expert in knowledge representation and responsible for the metadata management. The media studies faculties of Utrecht University and Royal Holloway, University of London complete the consortium.

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\* <http://www.europeandigitallibrary.eu/edlnet>

## 2.1 Catering for different users

The demand for access to television archive content online has been growing, and this demand has been driven from a number of distinct sectors: education the general public and the heritage sector.

British Broadcasting Corporation	UK
Danish Broadcasting Corporation	DK
Deutsche Welle	DE
Hungarian National Audiovisual Archive	HU
Institut National de l'Audiovisuel	FR
Istituto Luce	IT
Hellenic Audiovisual Archive	GR
Moving Image Communications Ltd	UK
Netherlands Institute for Sound and Vision	NL
Österreichischer Rundfunk	AT
Radio-Télévision Belge de la Communauté Française	BE
Swedish Institute for Sound and Image	SE
Televisio de Catalunya	ES
Vlaamse Radio- en Televisieomroep	BE

Table 1. The Video Active archive partners

Digitisation of archive content transforms cultural heritage into flexible 'learning objects' that can easily be integrated into today's teaching and learning strategies. For the academic community the rich holdings of television archives are valuable teaching and research resources. Up to now access has been limited with much of the archive content stored on legacy formats and minimum description. Although this is changing with many of the preservation and digitization projects underway in large audiovisual archives across Europe, the comparative dimension of European television content is not explored yet.

As noted in the introduction, the public demand for archive content has risen with the growth and affordability of the Internet and media publishing tools. Cultural heritage is of interest to everyone, not just specialists and students. The 19th century saw a huge development in museums, libraries, galleries and related heritage institutions, all with public access. Many such institutions have very low charges (or are free) in order to make access truly public and democratic. Audiovisual collections are much less accessible and democratic. Broadcast archives are closed to the public, most 'public' film and video institutions charge by the hour for personal access, and many such institutions are not actually public. Instead, they require proof of research status before allowing access to the general collections.

The digital age also has its impact on the work of professionals in the heritage domain, such as museum curators, organisers of exhibitions, journalists, documentalists, etc. They can conduct their activities and render services faster, better, more efficiently and sometimes at a lower cost. In short, a so-called e-culture is emerging. Additionally, in the digital age, the value of heritage institutions lies increasingly in their role as mediators between networks that produce culture and impart meaning. More and more, they will find themselves contributing their knowledge and content within a cultural arena where a host of highly diverse players are in action, including non-cultural sector institutions, as well as the audience or users.

This means that the added value of heritage organisations is increasingly dependent on the extent to which they are able to make knowledge sharing, crossovers, and structural cooperation part of their 'core business'.

These user groups have specific expectations and profiles, and the Video Active project has to understand and encompass these to ensure user satisfaction and revisits. Surveys, face to face interviews and desk research have been conducted in the initial stages of the project. The resulting insight in user requirements became fundamental to define the technical specifications and hence the technical architecture. Further requirements testing will take place on the first release of the portal; comprehensive evaluation with key users will provide the project with input at it develops the second release, planned for the second year of the project.

## 2.2 Content Selection Policy

By definition, the selected content on the Video Active portal is heterogeneous in many ways, language being one. A multilingual thesaurus allows multilingual access to the holdings. In the first release of the Video Active portal, ten languages will be supported.

Other challenges regarding the content selection strategy are related to the variety of archive holdings amongst the content providers for the project across both historical periods and genres. Also, the availability of supplementary content (images, television guides etc.) and metadata by the content providers is not spread equally amongst the partners. (Hecht 2007)

In order to tackle these issues, Video Active has developed a content selection strategy that followed a comparative perspective; seeking to explore and show the cultural and historical similarities and differences of television in Europe through various themes. The thematic approach allows for the development of a rich resource that explores the history of Europe using television archive content from across a number of genres and periods. So far 40 different themes have been selected and together with the historical coverage, a matrix for content selection has been created. This comparative approach is also reflected in the data-management and information architecture of the portal. The existing metadata in the archive need not only needed to be syntactically aligned, but also semantically enriched in order to enable the understanding and analysis of the material selected. Several Video Active specific fields were added to the Dublin Core element set\*, including Television Genre, European dimension and National relevance.

A final major factor influencing the content selection are the intellectual property rights (IPR) related to the programmes. In almost all cases, individual rights owners need to be contacted before material can be published online and agreements need to be set up. Material can not be made available until agreements have been set with all relevant parties involved. The project does not have the financial means to finance rights clearances, so needless to say, not all content that was selected in the first instance will find its way to the portal. Every country has different IPR regulations. In some cases for example, it's not allowed to store the video files on a server abroad. The Video Active infrastructure therefore needed to facilitate a distributed solution for content storage; where the central portal links to dispersed servers.

\* Dublin Core <http://dublincore.org>

### 3. THE VIDEO ACTIVE PLATFORM

The Video Active system comprises of various modules, all using web technologies. The whole workflow from annotating, uploading material, transcoding material, keyframe extraction, metadata storage and searching is managed by these components. Figure 1 shows the architecture behind the portal.

Video Active provides multilingual annotation, search and retrieval of the digital assets using the ThesauriX technology. ThesauriX is a web-based multilingual thesauri tool based on the IPTC standard. The system also exploits Semantic Web technologies enabling automation, intelligent query services (i.e. sophisticated query) and semantic interoperability with

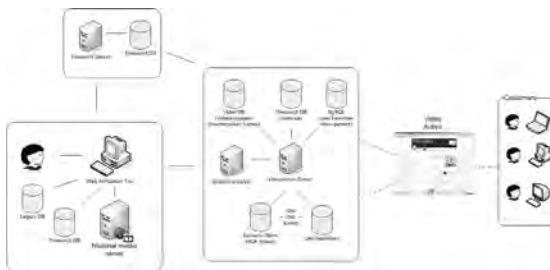


Figure 1: The Video Active Architecture

other heterogeneous digital archives. In particular, a semantic layer has been added through the representation of its metadata in Resource Description Framework (RDF).<sup>\*</sup> The expressive power of RDF enables light reasoning services (use of implicit knowledge through subsumption and equivalence relations), merging/aligning metadata from heterogeneous sources and sophisticated query facility based on SPARQL RDF query language.<sup>\*\*</sup> Additionally, XML and Relational database technologies have been used to speed up some process where semantic information is not required. Finally, the Video Active metadata are public and ready to be harvested using the OAI-MPH technology.

In the Video Active system each archive has the ability to either insert the metadata manually using the web annotation tool or semi-automatically using a uniform (common for all the archives) XML schema. The Video Active metadata schema has been based on the Dublin Core metadata schema with additional elements essential in capturing the cultural heritage aspect of the resources. The video metadata are produced automatically and are represented in a schema that is based in MPEG-7. In order to enable semantic services, the metadata are transformed in RDF triples and stored in a semantic metadata repository.

#### 3.1 Asset Management

The annotation process is either manually or semi-automatically. In the manual process, the archives are using the Web Annotation Tool to insert the metadata. In the semi-automatic process, the archives export their metadata (the ones that have mappings to the Dublin Core elements) using a common XML schema. The elements that cannot be mapped to

the Video Active schema (or are missing from the legacy databases, e.g. thesauri terms) are inserted manually

The Web Annotation Tool allows also entering and managing the metadata associated with the media and also handles the preparation of the actual content, i.e. format conversion (low/medium bit rate for streaming service, etc.).

It produces an XML file that contains metadata, based on Dublin Core, as well as content encoding and key frame extraction information. The XML is then transformed in RDF triples and stored in the semantic repository. The use of an ontology language, such as RDF that has formal semantics enables rich representation and reasoning services that facilitates sophisticated query, automation of processes and semantic interoperability. Semantic interoperability enables common automatic interpretation of the meaning of the exchanged information, i.e. the ability to automatically process the information in a machine-understandable manner. The first step of achieving a certain level of common understanding is a representation language that exchanges the formal semantics of the information. Then, systems that understand these semantics (reasoning tools, ontology querying engines etc) can process the information and provide web services like searching, retrieval etc. Semantic Web technologies provide the user with a formal framework for the representation and processing of different levels of semantics.

Encoding of the material is done by the archives. Ingest format (notably MPEG 1-2) are transcoded to Flash and Windows Media streaming formats by the so-called Transcoding Factory. The Transcoding Factory is integral part of the so-called Contribution Application; the heart of the asset management of Video Active.

#### 3.2 Storing and querying

The semantic metadata store that is used in Video Active is Sesame. (Broekstra 2002) Sesame is an open source Java framework for storing, querying and reasoning with RDF. It can be used as a database for RDF triples, or as a Java library for applications that need to work with RDF internally. It allows storing RDF triples in several storage systems (e.g. Sesame local repository, MySQL database). The procedure for the insertion of the assets into the RDF Store (Sesame) is depicted in Figure 3.

In order to transform the XML documents into RDF triples, Video Actives uses the Jena Semantic Web Framework.<sup>\*</sup> Jena is a JAVA API for building semantic web applications. It provides a programmatic environment for RDF, RDFS and OWL. In this application, Jena mainly for generating the RDF documents from the XML data representation. (Bechhofer 2004)

The query service of Video Active system has been based on the SPARQL RDF query technology. SPARQL is a W3C Candidate Recommendation towards a standard query language for the Semantic Web. Its focus is on querying RDF triples and has been successfully used to query the Video Active metadata. The end user has the ability to perform simple Google type searches but also allows browsing through the metadata using predefined filters, a way best compared with the Apple iTunes interface.

<sup>\*</sup> Resource Description Framework (RDF)  
<http://www.w3.org/RDF/>.

<sup>\*\*</sup> SPARQL Query Language for RDF,  
<http://www.w3.org/TR/rdf-sparql-query>

<sup>\*</sup> Jena – A Semantic Web Framework for Java,  
<http://jena.sourceforge.net/>

### 3.3 Metadata OAI Repository

All the metadata stored in Sesame, with the help of an OAI compliant repository are exposed to external systems/archives. The OAI-Protocol for Metadata Harvesting (OAI-PMH) defines a mechanism for harvesting records containing metadata from repositories. The OAI-PMH gives a simple technical option for data providers to make their metadata available to services, based on the open standards HTTP (Hypertext Transport Protocol) and XML (Extensible Markup Language). The metadata that is harvested may be in any format that is agreed by a community (or by any discrete set of data and service providers), although unqualified Dublin Core is specified to provide a basic level of interoperability.

## 4. THE VIDEO ACTIVE PLATFORM

This chapter shows the interface designs of the first version of Video Active, as launched in September 2008 at the FIAT-IFTA Conference. Figure 2 shows the homepage, figure 3 the subsequent results page and figure 4 the detailed view.



Figure 2: The Video Active homepage



Figure 3: The hitlist and filters



Figure 4: Part of the detail view

These interfaces will be evaluated with various end-users and will be amended according to the feedback gathered.

## 5. CONCLUSION

The European Commission's i2010 Digital Libraries initiative advocates the need for integrated access to the digital items and collections held in Europe's cultural heritage institutions via a single online access point; The European Digital Library.

Practical steps towards this goal are currently undertaken in many big and small projects. The EC recently launched a coordinative action to align these efforts, Europeana. Video Active is an invited member of the 'European Digital Library Thematic Partner Network' within Europeana. This network aims to bring on board key cultural heritage stakeholders from European countries to prepare the ground for the development of an operational service for the European Digital Library, to be operational in November 2008. Through Video Active's participation in EDLnet, semantic interoperability is facilitated between the two systems. Video Active has used all the late advances on Semantic Web technologies in order to exploit the full potential in representing, reasoning, querying and studying the Video Active metadata and content.

As this article has indicated, simply digitising and uploading archive content doesn't release the full potential of audiovisual content. The added value of archives lies in their ability to place material in a context meaningful to different user groups and by enriching the metadata to allow interactive exploration. For a pan-European service, the infrastructure should meet very specific requirements, dealing with semantic and multilingual interoperability, handing of intellectual property rights and so on. As more archives join Video Active, a vital part of our heritage will become available online for everybody to study and enjoy.

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# MODELING VIRTUAL SOUNDSCAPES: RECREATING THE 1950S WEST OAKLAND 7<sup>TH</sup> STREET WITHIN A MULTI-USER VIRTUAL ENVIRONMENT

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**KEY WORDS:** Soundscape, Game Audio, Multi-User Virtual Environment (MUVE), Cultural Heritage Reconstruction, West Oakland

## ABSTRACT:

This paper presents and discusses the technical, theoretical, creative challenges of virtually recreating and presenting the soundscape of a cultural heritage environment that no longer exists. The case study that is described is the virtual reconstruction of West Oakland California's 7th Street during the 1950's, at the time when it was a vivid cultural node famous with the music scene of its bars and clubs as well as its busy shops, hotels, restaurants and streetcars. We designed a Multi-User Virtual Environment (MUVE) with the aim of recreating the entire street, complete with its buildings, sounds and music, in a computer game format that unfolds as a hyper-textual story. It is assumed that a multi-modal representation of the environment as exemplified by our model will exponentially enhance the feeling of immersion, contribute to the sense of historic authenticity and ultimately increase the cultural and educational value of the project. The paper introduces the theoretical background of soundscape research, which is based on an extensive scholarship exemplified by the works of Schafer, Truax, Blesser and others. It explicates the methodology that has been followed, comprising specific algorithms and techniques built on top of an OpenAL-based 3D game audio framework. The process of generating the lifelike three-dimensional, interactive soundscape of the street is presented in detail, followed by a discussion of the applicability of the approach for other projects in the area of virtual cultural heritage representation.

## 1. INTRODUCTION

Existing attempts of virtual reconstruction of cultural heritage sites focus predominantly and exclusively on the visual, three-dimensional modeling of their physical environments. However, real places are often identified and remembered with their sounds (not to mention smells, tastes and other sensations) as well as their images. A reverberant Venetian square feels very different from a noisy street market in Istanbul. Hearing the call for prayer in Cairo, or the chimes of Big Ben in London, are indispensable bits that contribute greatly to the characteristic experience of these cities. Sound is an integral component that can change the perceptual character of any environment. Even subtle daily variations in the soundscape may drastically alter the experience of the same physical space.

Being the most spatial of all the senses, sound also bears the power of increasing the feeling of immersion within a space, be it real or virtual. Examples of previous research have demonstrated that the use of three-dimensional, localized sound in virtual simulations results in measurable increase in the sense of presence that is generated. (Bormann, 2005; Hendrix 1996) Even though research on the effects of immersive audio have mostly been carried out with specialized hardware, technological requirements for generating real-time 3D positional audio are now widely accessible to regular consumers. All popular gaming consoles ship with standard surround sound capabilities, and a great percentage of desktop PCs support feature sound hardware with equivalent specifications for surround sound support. This presents a great opportunity for cultural heritage reconstruction, as well as other cultural and educational uses of virtual environments. Yet is also a challenge: How would one reconstruct, and represent the sounds of a historic environment? Where exactly does one begin?

This paper introduces the theoretical background of soundscape research and discusses the methodology applied in recreating the soundscape of a cultural heritage site, a street in West Oakland, California. This street used to be particularly famous for its music and entertainment venues that contributed to its lively ambiance.

## 2. RECONSTRUCTING 7<sup>TH</sup> STREET

During the 1940s and 1950s, 7th Street in West Oakland was a bustling commercial district, anchored by dozens of jazz and blues clubs. The street was known as a West Coast rival of the Harlem music scene. It hosted a large population of African Americans from the South who used to work in the naval shipyards during the war, and stationed at the military bases along the Bay. The jazz and blues sounds from the musical establishments filled the 7th Street. Most of the legendary blues and jazz singers and musicians, as well as soul and rhythm and blues artists, performed at the clubs, including Jimmie McCracklin, Sugar Pie DeSanto and Ivory Joe Hunter. In fact, many famous musicians launched their careers by performing at 7th Street clubs. They defined a distinct Oakland blues sound and signed their first records with local music promoters like Bob Geddins and his Big Town recording studio and production company.

There were also numerous other business establishments within the eight-block stretch of 7th Street, all of which made the street one of Oakland's major commercial and social centers at the time. The street was home to colorful characters such as "The Reverend" who, along with his wife, preached from street corners, and Charles "Raincoat Jones," a former bootlegger turned loan shark and dice game operator, who was known as the unofficial mayor of 7th Street and helped finance some of the jazz and blues clubs.



Figure 1: Slim Jenkins bar/restaurant, West Oakland, c. 1950 (Photo courtesy of the African American Museum).

By the mid 1960s, there were great changes happening in the area. A remarkable part of this heritage was destroyed. During the 1950s, an elevated highway, named the Cypress Freeway, was constructed. It sliced across the 7th Street and effectively isolated it from the city's downtown. During the 1960s, another elevated structure, the Bay Area Rapid Transit (BART) rail and subway system, was constructed, creating a huge eyesore and deafening noise from passing trains. Around the same time, a stretch of several blocks along one side of 7th Street was removed to host a 12-square-block U.S. Postal Service distribution facility. Later in 1989, the Cypress Freeway collapsed during the Loma Prieta earthquake. It was then torn down and the freeway was re-routed around 7th Street, due to community pressure.

Today, the street is marked by boarded-up buildings and empty lots, and plagued by drug dealing and crime. Only a scattering of businesses now exist along 7th Street. The only remaining music club from the 1950s is Esther's Orbit Room. A walk down the 7th Street reveals almost no hint of the vitality of the area and the once thriving jazz and blues club scene.

Since 2005, the Digital Design Research Group at the Department of Architecture of the University of California, Berkeley, has been reconstructing the 7th Street into a multi-user virtual environment (MUVE) (Fig. 2). In this environment, multiple players can visit the street simultaneously through internet connections. They can explore the environment, interact with it, engage with the in-game characters and other players. Players can then obtain information about the history of the environment through all these interactions. The aim is to provide an entertaining and educational tool for young people to learn about the splendid history of West Oakland in its 1940s and 1950s. Although the environment we designed is technically speaking a Multi User Virtual Environment it also entails some aspects of a "3D adventure" game. This increases the engagement and appeal of the environment, and helps increase the game's pedagogical success.



Figure 2: Birds-eye view of the reconstructed 7<sup>th</sup> street.

In his study of architectural place, David Canter noted that places are made by the combination of three elements: physical spaces or the setting, people that generate and inhabit these settings, and their activities (Canter). Architecture, if taken as the physical component of place, is influential yet insufficient by itself to generate the genuine feeling of a place. Actual places are made by the people that inhabit them, and bear the live traces of their social activities. Designs for virtual places should consider this as a starting point and aim to represent the totality of place by being as faithful as possible to the social dimension of places as much as the physical (Kalay, 2004).

The trilogy of "physical setting, people, and activities" proves to be especially useful when the virtual environment in question is the reconstruction of a cultural heritage environment. In this regard, we aimed to carry out a holistic approach in our reconstruction project of Oakland's 7<sup>th</sup> Street as it was in the 1950s. Following a first person adventure style computer game format proved to be particularly versatile to accomplish this goal. In our game, the inhabitants of the street as well as the users are represented by custom-designed avatars wearing period clothing. Important characters of the time, such as famous musicians, club owners and community leaders are modeled in a lifelike manner and placed within the game for the users to interact with. In addition to interactive NPC's (Non Playing Characters) there are a large number of avatars or bots that act as a social backdrop and independently navigate the street, gather in groups, enter and leave bars, dance in front of the stage and engage in other social activities. The street also has two running cable cars, and many other vehicles that populate the street. In all its complexity and dynamism, our game came to be a lively virtual stage that, to the best of our knowledge and ability, looks and sounds like 7<sup>th</sup> Street in the 1950s.

### 3. SOUND AND PLACE

Several scholars within humanities, social sciences, media and communication argue for the significance of sound in the experience of places. Jacques Attali, in his seminal analysis on the socio-politics of sound and music notes, "More than colors and forms, it is sounds and their arrangements that fashion societies... All music, any organization of sounds is then a tool for the creation or consolidation of a community, of a totality" (Attali, 1985). Speaking of West Oakland, this statement carries particular value, since the music and the sound of 7<sup>th</sup> street was

the ultimate bonding element for the community. Indeed these sounds that used to emanate from the buildings eventually outlived the street itself.

The field of inquiry named Soundscape Studies, sometimes also called acoustic ecology, initiated by Canadian composer R. Murray Schafer (Schafer, 1977) and Communications Theorist Barry Truax (Truax, 2001), has emerged side by side with early years of environmental psychology during the 1970's. Schafer and his colleagues founded the World Soundscape Project and took their duty to document and preserve sounds of urban and natural spaces in a fight against mechanization of environmental sounds and noise pollution. They were among the first to come up with analytical methods and a terminological framework to map, document, and try to understand how different sonic environments function.

In line with the ambitions of early soundscape researchers, yet more than 30 years later, Blesser and Salter reminded us that what we hear and how we hear still matters for the experience of space (Blesser and Salter, 2007). What has changed within those years is that now we are looking at the concept of soundscape as something that we can digitally manipulate within architectural environments, or even generate from scratch in virtual simulations, thanks to the development in psychoacoustic simulation techniques, availability of high quality analog-digital and digital-analog conversion technologies coupled with much faster processing capabilities of today's hardware.

#### 4. CREATING THE VIRTUAL SOUNDSCAPE

While designing, modeling and scripting the visuals, buildings, avatars and their dynamics each have their inherent difficulties, coming up with the virtual soundscape of the street presented a genuinely challenging task different from any other. Although we had a considerable number of photographs, maps and written accounts of the street to take as visual reference and sometimes to literally use as texture maps for modeling the buildings, there was very little raw material on the auditory side. Our sources included oral histories, and some written descriptions of how the street sounded during the period. From the accounts of several "old timers," – people who remember the 1950s, have lived on or visited the street, or operated a business there during that time – we learned that it was a place with "stores and businesses bustling with activity," and had a "vibrant club scene" with sounds of live jazz and blues flowing out from the clubs and filling the street.

Ironically, the only sounds that one would be able to hear on 7<sup>th</sup> Street today are the loud, overwhelming noise of the Bay Area Rapid Transit (BART) trains that rip through the street with a frequency of every 6-to-7 minutes and the occasional police siren that marks the city's contemporary "acoustic horizon" (using Schafer's terminology). The unfortunate planning decision to place the BART overpass tracks along the center of the street had an undeniable role in the demise of the street, ultimately pushing people away from the neighborhood eventually leading to the closure of businesses during the late 1960s and early 70s. Several people who were interviewed for the project noted that the noise created by the trains made it impossible to make or enjoy music on the street. The fact that the authentic soundscape has long been wiped out of existence, made it inevitable for us to follow a somewhat speculative approach in our virtual reconstruction. We had to synthesize the soundscape by putting together bits and pieces of "found"

sounds, with the hopes of reaching at the complete sonic ambiance as it would have existed.

Some amount of 1950s music from 7th Street was recovered, passed down to our times in the form of vinyl albums and remastered Audio CDs. We were able to obtain permission to use pieces of recorded material from famous musicians who played on the Street, including the likes of Lowell Fulson and Juke Boy Bonner. These were studio recordings which are naturally very different from the musical ambiance one would experience in a live performance in a club. Nevertheless, this gave us enough to start with. We looked for places around with similar soundscapes as possible sources for inspiration and raw material. For instance, the sounds of cable cars in San Francisco were collected and edited to stand in for the cable cars of 7<sup>th</sup> Street. Places like New Orleans' Bourbon Street provided us with a living model to help envision the kind of sonic ambiance we should aim for. We also relied on samples from the Freesound Project at <http://www.freesound.org>, a large collaborative archive of Creative-Commons licensed sound recordings.

#### 4.1 Elements of the Soundscape

Kevin Lynch (1960) proposed a visual language to generate cognitive maps of cities. His model suggested five elements, namely 'paths, edges, districts, nodes, landmarks' as constitutive elements of the visual perception/composition of a city. According to Lynch's theory the spatial configuration of these elements formed the complete "image of the city" as perceived by its inhabitants. The same theory may apply to sonic environments as well as visual. The soundscape of any environment consists of many different types of sounds. These individual sounds that contribute to the totality of a soundscape can be classified according to their associative meanings and values for a particular context, and as for a particular group of people. Schafer (1977) approached sounds of an environment with a similarly analytical method, and he also developed a visual mapping language. He divided the elements that contribute to the soundscape as follows:

**Keynote sounds:** Background sounds defining the overall sonic characteristic of an environment.

*Examples: Sounds of traffic in Times Square, birdsongs in a forest.*

**Signals:** Foreground sounds that are attentively listened because of their informational content.

*Examples: The sound of news on TV, chimes of a bell tower when it strikes the hour.*

**Soundmarks:** Derived from the term landmark – refer to community sounds which are unique or possess special cultural qualities.

*Examples: Sounds of cable cars in San Francisco*

**Symbols:** Archetypal sounds that carry deep cultural, historical or religious symbolism.

*Examples: Call for prayers, chimes of bells.*

One is supposed to keep in mind the categorization of a particular sound can easily shift from one to the other depending on the context of listening and the purpose of the listener. A signal, for instance an advertisement on the radio, which is not consciously attended to ceases to be a signal and merges into the background. A ship horn can be a signal for a captain trying to navigate his ship in the fog; yet for another person, it can

function as a soundmark – a sound that carry sentimental, cultural, etc. connotations. Soundmarks and symbols are particularly overlapping categories; therefore, they are grouped together in the classification shown in the table below which lists some of the sound sources we envisioned for 1950’s 7<sup>th</sup> Street.

<p><b>Keynote sounds</b> <i>(Background)</i></p>	<ul style="list-style-type: none"> <li>- Sounds of traffic, including cable cars</li> <li>- Various crowd sounds in bars, restaurants and pool halls</li> <li>- Sound of children playing on the side streets</li> <li>- Sounds of musicians practicing their instruments</li> <li>- Natural sounds including occasional dog barks, bird songs coming from trees (not many trees were on the street).</li> <li>- Construction noises (Cypress Freeway construction)</li> <li>- Industrial noises (Shipyard)</li> </ul>
<p><b>Signals</b> <i>(Foreground, w/ generic character and pragmatic use)</i></p>	<ul style="list-style-type: none"> <li>- 1950s advertisements playing on the radio</li> <li>- Yells of street sellers including a tamale-man and shoe-shiners</li> <li>- Car horns</li> <li>- Cable car bells</li> </ul>
<p><b>Soundmarks / Symbols</b> <i>(Foreground - w/ high cultural significance)</i></p>	<ul style="list-style-type: none"> <li>- Jazz and Blues bands playing in clubs</li> <li>- Music playing from jukeboxes</li> <li>- Gospel music flowing out from churches</li> </ul>

Table 1: The soundscape elements for West Oakland 7<sup>th</sup> Street in the 1950’s.

It is also important to recognize that, just as Lynch’s visual mapping methods were not meant to be used directly as a design tool, the classification of sounds listed above is not particularly intended for designing soundscapes but analyzing them. Bearing this in mind, the categories mentioned can serve as a design guide for rethinking the elements that constituted the soundscape of 1950’s West Oakland.

**4.2 Spatial Distribution of Sounds**

Once an overall list of sounds were made and the necessary samples were collected from the sources mentioned, the next task was to organize them in space and time so that they would blend together into a coherent and interesting whole. With the assistance of Marc Moglen, an undergraduate research apprentice and a Musicology student, we decided to treat this as a design problem, or even a case of musical composition. The concept was to recreate the sonic experience of a visitor walking through the 7<sup>th</sup> Street listening to it freely, and coming into the appreciation of the nuances between different zones with distinct identities and dynamics. We used Google Earth to visualize the spatial distribution of the sounds, which functioned as a means of notation, design, and also simple

archival system for storing and referencing our list of sound effects. (Fig. 3) By using media tags for each location we were able to store lists of sound effects, their explanations, and were also able to listen to them separately from each other before inserting them into the game.

Using Sanborn Maps and other sources we found out that the street had groups of similar businesses clustered around specific zones. The block where Slim Jenkins’ club existed marked the main center of attraction surrounded by several other clubs and bars. This area, marked by the live music flowing out from the clubs, was labeled the “Center of Attraction.” The three other sonic zones on the street were the “Residential,” a stretch with domestic sounds; “Urban,” an area where shops restaurants and a large theater used to be and a “Transitional” zone that stood between the Clubs and the Ports, with several Hotels and clubs that used to host sailors and train porters who frequented the street.

On the East side, the street was blocked by the Cypress Freeway, the construction of which was in progress during the 1950s. The West end of the street was marked with the sounds reaching from the shipyard. These two ends defined the two opposite acoustic horizons of the street, marking the border of the perceived acoustic space.



Figure 3: The Google Earth map, which was used to designate the four sonic zones and manage original sound sources that are organized by location.

**4.3 A “Sonic Foliage” Generator**

A major challenge in designing environmental sounds is the issue of looping. People easily notice looping sound effects especially if identifiable events or objects exist in a relatively short loop. When an obviously detectable loop exists in the background sounds, it not only breaks the suspension of disbelief but also can be very distracting and annoying for the user. As with all other natural phenomena, sounds of a real environment carry great amount of unpredictability hidden behind an overall perception of order. Simulations aiming for realism can achieve this effect by utilizing simple pattern randomization or more complex stochastic processes.

For our simulation we designed and programmed an algorithm which schedules the timing and manages the placement of sound effects, triggering them according to parametric input for location, frequency, and randomization factors for both frequency and location. All of these parameters were provided for individual point sources which needed to be non-periodical.

Sound samples were processed to avoid sharp cuts in the beginning or end. Fade-ins and fade-outs were added as necessary. When overlaid on top of a low-amplitude environmental loop, these foreground sounds generate a certain degree of dynamism and unpredictability to the background, generating a sense of presence, activity and naturalness. We successfully utilized this algorithm for both interior and exterior audio zones within the street.

#### 4.4 Implementation of Spatial Acoustics

In our MUVE, sounds placed within the environment model are localized and attenuated by the sound hardware, depending on the user's location and head direction within the environment. Localized sound is particularly important to provide a sense of directionality and depth to the 3D environment. Perspective rendering of the viewport can only show a narrow visible portion of the virtual space, as seen from the small window of the game screen. The graphic window can only give a sense of uni-directional presence, since we are only visually aware of what is in front of us. However, hearing gives us a sense of space that is omni-directional, a sense of being surrounded within space. Phenomenologically speaking, a virtual environment that utilizes 3D audio in addition to visual models engenders a much more comprehensive sense of presence.

Due to the taxing computational requirements of implementing real-time software algorithms to simulate environmental-acoustics, and problems of compatibility that may arise from using real-time hardware-based environmental extensions as well as the proprietary nature of those (such as Creative Systems' EAX-4.0), the spatial acoustic effects like reverberation, echoes and coloring, are "baked" onto the sound sources themselves. For instance, the sounds of gospel music coming from within the 7<sup>th</sup> Street Mission, is a looping sample that is manually pre-processed to reflect the way the sounds would be first reverberated within the room, then muffled by the outer wall of the church. All of the interior sounds are also pre-processed to reflect the acoustic characters of spaces that they belong to.

Another environmental effect that we simulated using simplified methods was the acoustic occlusion caused by the building walls. Several interior audio zones and a single exterior zone were mapped onto the environment and outputs of these were assigned to discrete audio channels. Pseudo-realistic physical occlusion was achieved by selective mixing, or muting of these interior and exterior audio channels based on the location the user is standing at. For instance when the user is right outside Slim Jenkin's bar, hence also outside it's audio zone, sounds of the bar are suppressed while the sound of the street is amplified. When the user enters the bar, the opposite happens. This creates the illusion that the wall in between two spaces has actual thickness that reduces sound transmission. More recent gaming engines, unfortunately not Torque, employ realistic 3D occlusion through polygonal occlusion meshes, yet our system seems to adequately fulfill the needs of the project.

#### 4.5 Diegetic vs. Non-Diegetic Sounds

Following a terminology originating from film theory, the sounds of a narrative virtual environment can be classified into two main categories. The first one is the *diegetic*, comprising of sounds that belong to and emerge from the narrative space. The ambience of the street, music emanating from the bars, sounds of people, conversation, cars and so on are all part of this group. The second category is the *non-diegetic*, which includes sounds that do not belong to the story world, but overlaid on top of it for informational or narrative purposes, sometimes to enhance other times to distract from the realism of the represented world. In the world of computer games and other interactive environments the dualism of the diegetic vs. non-diegetic applies to visuals more significantly than it does in film. An avatar representing a character in the game is diegetic since it belongs to the virtual world, whereas the "Save Game" or "Inventory" buttons as well as the on-screen chat window are non-diegetic. The design of any virtual environment should factor in the necessary interplay of the two modes of interaction, competing with yet at the same time complementing each other.

Diegetic sounds are the sounds that contribute to the experience of the sonic landscape of the environment that is represented. Introducing a rich variety of sounds that are intricately layered in time and space as well as the sonic spectrum can drastically increase the layer of realism and contribute to the feeling of immersion.

Non-diegetic sounds necessarily carry with them an effect of alienation, because they call attention into the presence of an interface layer that stands in between the virtual world and the real one. Generally speaking, this works against the primary goal of virtual simulations, which is based on the premise to make the interface as transparent as possible. Although it can be theoretically argued that this reduces the suspension of disbelief in the user, it is also arguable that non-diegetic sounds can function to increase the effectiveness of the narrative and improve the sense of responsiveness and help improve interactivity.

#### 4.6 Musical Interaction as Participation

Both phenomenology and communication theory agree on the fact that we experience the environment by enacting our bodily and sensory presence. Participation is essential in any sensory perception leading to a sense of presence, implying we are not passive observers; and that we have engage in active probing in order to perceive anything. (Noe, 2004) Further readings into the phenomenology of the senses lead us to the argument that sensory participation, making noise, to be seen, heard, touched etc. are also essential and formational for sensory and spatial experience. (Rodaway, 1994) This may be more important for the auditory dimension of the senses than the visual. Truax notes, "unlike the passive quality of 'being seen,' the listener must make an active gesture to be heard" (2001). According to this theory sense of presence in virtual space will enhance when it can be manifested sonically by the actions of avatars that generate noise, in addition to visually by the avatars geometric models themselves.



Figure 4: Jamming with the live band in Slim Jenkins' Bar

In the West Oakland MUVE, a degree of auditory participation is allowed through a set of interactions. Firstly, interactive objects such as jukeboxes respond to user actions by playing music or sounds. Secondly the users can “jam” with the band playing on the stage at the Slim Jenkin’s bar. The users can jump on the stage and play musical instruments by pressing keys on their keyboard. Pre-recorded riffs are assigned to different keys on the user’s keyboard, and the user can decide on the order in which the riffs get played. In the meanwhile the rest of the band plays a 12-bar blues pattern to act as a musical background for the soloing players. The other users can also hear what’s being played, and respond by dancing in front of the stage, clapping etc. (Fig. 4)

## 5. TECHNICAL INFORMATION

The West Oakland MUVE is developed using Torque Game Engine, a commercially available kit for developing Internet-enabled multi-user 3D games ([www.garagegames.com](http://www.garagegames.com)). The server module of the engine maintains a stable representation of the virtual environment, and manages communications with the client modules interconnected through a TCP/IP network. The engine allows for script programming of the in-game events and interactive behavior of objects in the environment as well as the user interface. 3D Modeling for the game was done in 3D Studio Max, and the game’s proprietary editor named Constructor. Avatar modeling was carried out using Poser and 3D Studio Max. Audio files were processed and edited using Audacity.

On the client module, the engine utilizes the OpenGL subsystem for graphics rendering, and in combination uses the OpenAL API to deliver 3D Audio. OpenAL (Open Audio Language) is a cross-platform application programming interface that is designed to program and render three-dimensional positional audio. This gives the flexibility to design the sounds of the game in an abstract manner, independent of the specifics of hardware configuration. For instance, one user may be using a high-end desktop system with 7.1 speaker surround output, while the other may be using a notebook with low-end sound support and stereo earbuds. Whichever the case may be, the local implementation of the OpenAL should ensure the best possible quality for rendering environmental audio enabled by the capabilities of the available hardware configuration.

## 6. FUTURE WORK

Due to the limitations of time and resources, we were not able to implement some functionality that could have further improved the sonic complexity of the environment, and helped increase the level of interactivity and feeling of presence. Some of these are the capability of supporting voice-chat between users, voice-overs for NPC dialogs, and more variety and flexibility in terms of musical expression for the jamming sequences.

At this stage, a structured evaluation of the perceptual and cognitive effects of the use of sound within our simulation has not been carried out. We are expecting initial feedback from the prospective users and students after which we plan to carry out controlled tests to assess the various claims of our project. We publicly released the MUVE and started to allow online logins and feedback through the project website.

## 7. CONCLUSION

Environmental sound, when used correctly, can breathe life onto any Virtual Environment. Tuan reminds us that the organization of human space is primarily dependent on sight. However other senses expend and enrich visual space expanding its dimensionality and realism. Sound widens a person’s spatial awareness to include areas behind the head that cannot be normally seen. Sound also makes spatial experience more engaging and dramatic. (Tuan, 1977) It was our starting belief that we can readily assume this argument applies also to virtual environments that aim to recreate the realism and liveliness of actual places.

Virtual places also suffer from a sense of materiality. Material substance is poorly represented by visual models that try to substitute for the lack of tactility by colors, shadows and textures. Introduction of sound can contribute to the feeling of materiality and spatiality together, as it does in real space, by giving us acoustical cues of hardness and softness, smallness and largeness, closeness and farness. Sound, as a necessarily temporal sense adds a previously not existing dimension to virtual places, making them closer to live events than static images. Both human presence and the lack of it, flows and natural variations in space can be represented readily through sound. Music and language adds an even deeper dimension to virtual environments. They function as soundmarks, setting the cultural context, as well as environmental character, ambiance, and mood of a space.

In this paper a case study of modeling the soundscape of a virtual cultural heritage environment was presented. The methodology described here is strongly influenced by the early Soundscape theory initiated by Schafer and Truax, and shaped by the contemporary capabilities of a gaming engine and commercially available sound hardware. We hope that our attempt will initiate a discussion, evoke further interest and provide encouragement for other projects that will utilize sounds, and multi-modal interaction, in support of traditional visual modeling to represent architecture and cultural heritage.

Current version of the game “Remembering 7<sup>th</sup> Street: West Oakland Jazz and Blues” can be downloaded from our website at [ddr.ced.berkeley.edu](http://ddr.ced.berkeley.edu).

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## FOCUS K3D: PROMOTING THE USE OF KNOWLEDGE INTENSIVE 3D MEDIA

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### ABSTRACT:

In recent years, 3D content has become more and more widespread and have been made available in a plethora of online repositories. A systematic and formal approach for capturing and representing related knowledge/information is needed to facilitate its reuse, its search and retrieval, and enable the demonstration of useful applications. In this paper we present the FOCUS K3D Coordination Action which aims to foster the comprehension, adoption and use of knowledge intensive technologies for coding and sharing 3D media content in consolidate and emerging application communities like Cultural Heritage & Archaeology, Medicine & Bioinformatics, Gaming & Simulation and CAD/CAE & Virtual Product Modelling.

### 1. INTRODUCTION

During the last decade there was an explosion of multimedia content and a rapid improvement in technologies for its access and retrieval. To address the emergence of these new needs in the area, semantic multimedia have been proposed as a new paradigm that encapsulates the convergence of multimedia and knowledge technologies as the evolution of traditional multimedia, and which makes it possible to use, share and access digital content in distributed or networked environments. 3D content plays a crucial role in intelligent digital content creation and consumption. On one hand, Computer Graphics has reached quite a mature stage where fundamental problems related to the modelling, manipulation and visualization of static and dynamic 3D shapes are well understood and solved. On the other hand, technological advances highly reduced the costs of 3D content acquisition, storage and transmission, making it possible to deliver and manipulate 3D content.

Digital representations of 3D objects provide information serving a number of application purposes. The massive impact of 3D content in everyday life can be already observed in application domains spanning from edu-entertainment to scientific visualization. Examples are provided by virtual games and consoles where 3D models are used and manipulated in order to create virtual worlds for simulating wars, battles, car competitions and so on.

In the last few years we have seen a large growth in repositories of 3D content from different sources and contexts. 3D data are not only related to graphical aspects, they are also endowed with high knowledge value, either due to the expertise needed to design them or to the information content carried. This knowledge is of different kinds. Knowledge related to the geometrical and visual aspects which are captured by a set of geometric and graphical data representing the digital object. Knowledge related to the purpose/role of the object represented which defines its category or functionality. Knowledge related to the application domain which has to cast its rules on the way the 3D data are represented, processed, and interpreted.

In this context, the FP6-IST Network of Excellence AIM@SHAPE (AIM@SHAPE, 2005; Falcidieno, B., 2004) introduced knowledge management techniques in visual media with the aim of making explicit and sharable the knowledge embedded in multi-dimensional media, with focus on 3D content. This required the development of both ontologies and knowledge bases capable of describing 3D objects and processes, and data structures and tools used to associate semantics to 3D models. It was also necessary to build a common framework for reasoning, searching and interacting with the semantic content related to the knowledge domain. This platform is the Digital Shape Workbench or DSW (DSW, 2008), one of the main outcomes of AIM@SHAPE, a common infrastructure which incorporates software tools, visual media databases, and a digital library, all built on the basis of suitable ontologies and metadata.

3D content is emerging also in several EU projects. SALERO (SALERO, 2006), for example, approaches the problem of associating the semantics to 3D content but with specific focus on building an expert system for processing and repurposing digital content for gaming applications, and 3D is one type of content considered. Since gaming is the only application field considered, the range of issues to be addressed for 3D content and its semantic descriptions are limited to a single and rather simple type of 3D representation. VICTORY (VICTORY, 2007) targets 3D content from the point of view of the development of a search engine to retrieve 3D and associated multimedia-distributed content in peer-to-peer and mobile networks. In this case, however, the issue addressed is concerning more the retrieval of the content rather than the modelling of the semantic aspects of 3D objects. Finally we should also mention SCULPTEUR (SCULPTEUR, 2005) which developed new modes of information retrieval and collection exploration by combining Semantic Web and content-analysis techniques to allow searching by concept, metadata and content.

Embedding semantics and domain knowledge in 3D-intensive applications can highly improve the content creation pipeline in terms of speeding-up the process and allowing a concrete re-use



of valuable resources (e.g., existing content, processing tools, workflows). Semantic description of multimedia items has been mainly developed for audio, video and still images. Domain-specific ontologies are focused on describing the content and the parts of a multimedia scenario, such as elements in a scene, colours, motion duration, etc. These descriptions are defined in order to be able to categorize, retrieve and reuse multimedia elements. Examples of domain-specific ontologies and metadata have been developed for a wide set of applications, from Cultural Heritage (Doulaverakis, C., 2005) to Biomedicine (Catton, C., 2005).

AIM@SHAPE suggested a high-level subdivision of the knowledge carried by digital representations of 3D objects into three levels of granularity with respect to their knowledge content: the *geometric*, *structural* and *semantic* levels. Ontology development in AIM@SHAPE has been mainly focused on three different areas: Virtual Humans (Gutierrez, M., 2005), Shape Acquisition and Processing (Papaleo, L., 2005; Ucelli G., 2005), and Product Design.

The approaches developed so far are either too general for being immediately useful in real application domains or too specific to one single domain. Therefore, to avoid that recent research outcomes in the representation and processing of the semantics of 3D media remain confined to individual communities of researchers or professionals, it is necessary to promote and coordinate dissemination actions targeted at demonstrating the accessibility and viability of these results in a number of important applied sectors. A fast evolution of the research in the field is conditioned by the ability to create interdisciplinary research teams able to communicate with the application domains that produce and use 3D content. 3D is spreading out of the traditional circles of professional users and it will soon reach new audiences.

## 2. SEMANTIC 3D MEDIA

3D media are digital representations of either physically existing objects or virtual objects that can be processed by computer applications. 3D content is widely recognized as the upcoming wave of digital media and it is pushing a major technological revolution in the way we see and navigate the Internet. Beside the impact on entertainment and 3D web, the ease of producing and/or collecting data in digital form has caused a gradual shift of paradigm in various applied and scientific fields: from physical prototypes and experience to virtual prototypes and simulation. This shift has an enormous impact on a number of industrial and scientific sectors, where 3D media are essential knowledge carriers and represent a huge economic factor in many content sectors.

Thanks to the technological advances, we have plenty of tools for visualizing, streaming and interacting with 3D objects, even in much unspecialized web contexts (e.g., SecondLife). Conversely, tools for coding, extracting and sharing the *semantic* content of 3D media are still far from being satisfactory. Automatic classification of 3D databases, automatic 3D content annotation, content-based retrieval have raised many new research lines that represent nowadays some of the key topics in Computer Graphics and Vision research. At the same time, knowledge technologies, such as structured metadata, ontologies and reasoners, have proven to be extremely useful to support a stable and standardized approach to content sharing, and the development of these techniques for

3D content and knowledge intensive scenarios is still at its infancy.

FOCUS K3D believes that *semantic 3D media*, as the evolution of traditional graphics media, make it possible to use and share 3D content of multiple forms, endowed with some kind of *intelligence*, accessible and processable in digital form and in distributed or networked environments. The success of semantic 3D media largely depends on the ability for advanced systems of providing efficient and effective search capabilities, analysis mechanisms, and intuitive reuse and creation facilities, concerning the content, semantics, and context.

## 3. FOCUS K3D MAIN OBJECTIVES

The aim of FOCUS K3D Coordination Action is to foster the comprehension, adoption and use of knowledge intensive technologies for coding and sharing 3D media content in consolidate and emerging application communities. In particular, the project focuses on the following domains: Cultural Heritage & Archaeology, Medicine & Bioinformatics, Gaming & Simulation and CAD/CAE and Virtual Product Modelling.

The main objectives of the project are: a) to exploit the scientific and technological advances in the representation of the semantics of 3D media to increase awareness of the new technologies for intelligent 3D content creation and management; b) to build user-driven scenarios to evaluate and adapt the technologies so far developed to the requirements of application environments and c) to foster a shift of role of 3D content users, from passive consumers of technologies to active creators.

FOCUS K3D wants to improve the awareness that new ways are needed for making 3D contents that embody creativity and semantics easier to produce, organize, search, personalize and use, addressing the needs of their creators and users. What we will pursue is:

- To build multi-disciplinary communities of researchers, 3D professional content creators and users/producers both in consolidated fields, like product design and manufacturing, and in emerging new areas, like gaming and bioinformatics;
- To carry out rigorous analyses to identify technical or other (e.g. cultural, legal) issues that currently inhibit a broader user participation in the production, reuse and sharing of 3D content, and initiatives that would act as catalysts for such a development;
- To promote and evaluate the results achieved by recent and ongoing projects in the field of 3D media semantics representation and processing, in order to identify promising future developments for a broader use of them;
- To contribute to the adoption of best practices concerning the dissemination, re-use, and preservation of valuable scientific knowledge and resources in terms of 3D models, software tools for 3D manipulation and processing, as well as ontologies and metadata describing content and knowledge related to the typical workflows underlying and contributing to 3D media modelling and processing.

FOCUS K3D will achieve its objectives through an energetic coordination of actions devoted to the elicitation and elaboration of the requirements and desiderata of the various communities with respect to 3D content authoring and processing, as well as

actions devoted to the dissemination of available research solutions to a wide community of users. The coordination strategy will be implemented by the set up of four application working groups (AWGs), one for each identified application area mentioned above, in order to better organise and customise the dissemination activities according to the needs of the specific fields. The AWGs are coordinated by FOCUS K3D partners, who will promote discussions, solicit position papers and presentations, invite new users to the AWGs, and formulate ad hoc questionnaires and interviews.

In order to be able to demonstrate in practice the advantages of using semantic 3D shapes, FOCUS K3D will use an adequate infrastructure support, as the one offered by the Digital Shape Workbench (DSW) of the AIM@SHAPE NoE that provides the functionalities for sharing 3D resources and accessing them via formalised knowledge, either as metadata or as ad hoc ontologies. To the extent of our knowledge, the DSW is unique in its role; however, any other existing infrastructure that offers the same functionalities could be used.

#### 4. THE CULTURAL HERITAGE AND ARCHAEOLOGY APPLICATION WORKING GROUP

The domain of cultural heritage and archaeology is characterized by an increasing volume of 3D digital resources. The use of 3D data is not only related to visual aspects and rendering processes, but it involves also an adequate representation of domain knowledge to exploit and preserve both the expertise used for their creation and the information content carried.

Museums and galleries are becoming increasingly rich in digital information. This information is often created for internal activities such as cataloguing, conservation and restoration, but also has many additional uses including gallery terminals, Web access, educational, scientific, and commercial licensing. 3D models and virtual spaces have huge potential for enhancing the way people interact with museum collections; for example, in structured e-learning environments. However, 3D content is often hard to access and is held in multiple internal systems with non-standard schemas and descriptions. This makes it difficult to expose this rich source of information to be used over the Web in external applications.

On one hand, 3D semantic modelling can be beneficial to provide documentation in case of loss or damage, and interactions with precious artefacts without risk of damage. On the other hand, it can be efficiently employed for educational purposes, such as virtual tourism, virtual museums and 3D visualization of city buildings and monuments.

The first kind of activities include the acquisition and reconstruction of artefacts, providing high geometric accuracy in the digital models, photo-realism, full automation, low cost, portability and flexibility in applications, while minimizing human interaction during the modelling process. The association with semantics is also crucial to visualize the models properly and retrieve them efficiently from large databases. Efficient retrieval implies equipping 3D content with metadata related to both the whole object and its subparts, developing automatic metadata extraction tools and shape similarity mechanisms to compare objects, providing best practices assisting the processing phase.

The second kind of activities is strictly related to the Virtual Reality issues and, in this sense, has a connection with the Gaming and Simulation field. Numerous articles and documents have underlined the importance of ensuring that 3D visualization methods are applied with scholarly rigour, and that the outcomes of visualization inclusive research should accurately convey to users the status of the knowledge they represent.

Effective 3D search and retrieval is a major challenge and could have significant impact to the domain of cultural heritage and archaeology.. For instance, a next generation search mechanism for 3D content could integrate content-based geometry-driven criteria with concept-based semantic-driven ones (see Figure 1). This search engine can be based on an innovative query formulation and support geometric, semantic and combined search modalities. For example, it could be possible to pose queries such as *“find the 3D models in the repository that represent a vase with handles, and whose handles are globally similar in shape to a given query model”*. In the example *“vase”* and *“handle”* could refer to semantic annotations and be resolved via a semantic search, whereas *“handles are globally similar in shape”* will be resolved by applying a geometric search to the models selected by the semantic search. This kind of query formulation interface will provide the unprecedented capability of capturing the intuitive notion of similarity expressed by the user in the query session.

The main interest of this Application Working Group focuses on the organization and presentation of cultural heritage/archaeological content to “virtual visitors” (virtual exhibits). Other areas of interest include the development of educational and training applications for real and virtual artefacts, landscape archaeology, recreation and 3D representation of the past landscapes and past habitation environments, restoration, reconstruction and visualization of artefacts. Members of this AWG include Universities and research labs, museums, educational organizations and 3D vendors/creators. FOCUS K3D aims at bringing together researchers and industries in Europe that are capable of identifying the needs of the users regarding 3D shape knowledge representation and processing. Moreover, through its dissemination activities it will create awareness of the benefits deriving from the re-use, and preservation of valuable scientific knowledge and resources in terms of 3D models, software tools for 3D manipulation and processing, ontologies and metadata.

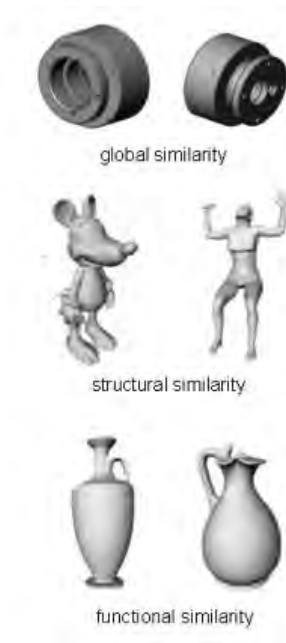


Figure 1: Ease the retrieval of 3D content by effective search mechanisms

## 5. EXPECTED RESULTS AND CONCLUDING REMARKS

Currently in widespread use for entertainment, computer-aided design and manufacture, 3D digital content is becoming crucial in areas like culture, education, medicine and bioinformatics, and equally essential in developing convincing virtual worlds. Therefore we foresee an always-increasing use of 3D models both at personal and at professional levels as it has happened for images and videos.

Ontologies have already started playing a crucial role in Cultural Heritage by helping heritage practitioners and professionals with moderate computer skills understand the cultural and digital information embedded in complex heritage 3D objects (Kanellopoulos, D, 2006). As an example we might consider a relatively early effort to develop an ontology that allows 3D presentation of cultural objects to act as a querying interface, allowing high-level visual access to the ontological knowledge base.

Semantics is, and in fact has always been, an integrated part of Museums. Museums were among the first cultural institutions to recognize the importance of metadata and their organization. So, it is not surprising that they are also among the first to seriously consider the semantic web for their more digitally connected future (Redfern, T., 2004). FOCUS K3D has the potential to contribute to several already established projects in this direction.

Educational issues in Archaeology and Cultural Heritage are surely important and have already attracted the attention of both the scientific community and the institutions associated with heritage of humanity and its environment (Kanellopoulos, D, 2006). As an example we might consider the Danish German Virtual Museum which is essentially a semantic portal, in the sense that it is a relatively content-heavy Web site which is completely ontology-based (Niccolucci, F., 2006). The ontology

already developed allows for the content to be organized according to a so-called didactical concept that essentially break the historical content down into a number of manageable learning units, which are assembled into a number of meaningful sets. An ontological organization of the 3D content of the Museum can readily add helpful educational component on a rather complex issue either directly as in the above example or implicitly (Parisi, S., 2007) though semantically based animations for training.

It is expected that the semantic organization of Cultural Heritage will soon benefit from ontologies that are being developed in thematic areas related to Humanities in many ways; for example by coupling them with ontologies for 3D artefacts. Although there is still no overview of what exists, which standards are used and how well the current ontologies in Humanities meet the users requirements; the amount of recent research and development efforts, e.g. the EPOCH (EPOCH, 2007), and following two recent workshops: *Ontology Based Modelling in the Humanities* – April 2006 and *Building Ontologies for Humanities and Social Sciences* – March 2007, allow us to be very optimistic.

Various web-based electronic services for Archaeology could also receive valuable direct support from FOCUS K3D efforts. Such services include (but are not limited to) various existing and emerging electronic scholarly publication services (Kling, R., 2003) which rapidly move from traditional text publishing to peer-reviewed digital content publishing e.g. the “*The Archaeology Data Service (ADS)*” the “*Internet Archaeology*” the “*Digital Humanities Quarterly (DHQ)*” and in particular the “*SAVE (serving and archiving virtual environments) e-Journal\**”, a new journal for digital archaeology to be launched in 2009.

From our perspective, the full exploitation of the potential offered by 3D virtualization, and consequently its success, depends on two issues: the capability of dealing with new and complex types of digital 3D content, and the ability to influence the approach to 3D object creation in a range of application areas that go beyond mere visualization. In this sense, we foresee that FOCUS K3D will:

- Boost new research and innovation via the set up of new ways that allow to create, process, and re-use 3D scientific resources, and the convergence of the research agendas in the scientific communities
- Increase synergy between the scientific community and the professional users of 3D content in applied sectors, to enable a better knowledge transfer to industry and society
- Help to involve individuals as active creators, mixers and promoters of 3D media

## 6. ACKNOWLEDGEMENTS

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\* [http://www.caa2008.org/topi\\_absworkshop2.html](http://www.caa2008.org/topi_absworkshop2.html)

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## ABSTAND: DISTANCE VISUALIZATION FOR GEOMETRIC ANALYSIS

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**KEY WORDS:** Computer-aided design, mesh processing, geometric errors

### ABSTRACT:

The need to analyze and visualize differences of very similar objects arises in many research areas: mesh compression, scan alignment, nominal/actual value comparison, quality management, and surface reconstruction to name a few. Although the problem to visualize some distances may sound simple, the creation of a good scene setup including the geometry, materials, colors, and the representation of distances is challenging.

Our contribution to this problem is an application which optimizes the work-flow to visualize distances. We propose a new classification scheme to group typical scenarios. For each scenario we provide reasonable defaults for color tables, material settings, etc. Completed with predefined file exporters, which are harmonized with commonly used rendering and viewing applications, the presented application is a valuable tool. Based on web technologies it works out-of-the-box and does not need any configuration or installation. All users who have to analyze and document 3D geometry will stand to benefit from our new application.

## 1. INTRODUCTION

Analyzing differences between surfaces is a necessary task in many fields of research. Measuring the distance between two surfaces is a common way to compare them. In computer graphics, for example, differences of surfaces are used for analyzing mesh processing algorithms such as mesh compression. They are also used to validate reconstruction and fitting results of laser scanned surfaces. As laser scanning has become very important for the acquisition and preservation of artifacts, scanned representations are used for documentation as well as analysis of ancient objects. Detailed mesh comparisons can reveal smallest changes and damages. These analysis and documentation tasks are needed not only in the context of cultural heritage but also in engineering and manufacturing. Differences of surfaces are analyzed to check the quality of productions.

A meaningful visualization of surface differences is a challenging task. The goal is a clean representation of facts without overextending the observer. This can be done using still images and also using interactive rendering. Universal 3D files (U3D) embedded in a Portable Document File (PDF) allow to publish and share interactive visualizations on a wide-spread platform.

This paper presents an application which optimizes the workflow to create such visualizations. It uses a classification scheme to group typical scenarios. Reasonable presets of settings are provided for quick output generation. The results can then be imported into common visualization tools like Maya<sup>TM</sup>, 3ds Max<sup>TM</sup>, or Deep Exploration<sup>TM</sup> to support the overall visualization task.

## 2. RELATED WORK

Our application visualizes distances between geometric objects. It is related to three areas of research. The distance calculation itself is an algorithmic problem. The visualization has to deal with

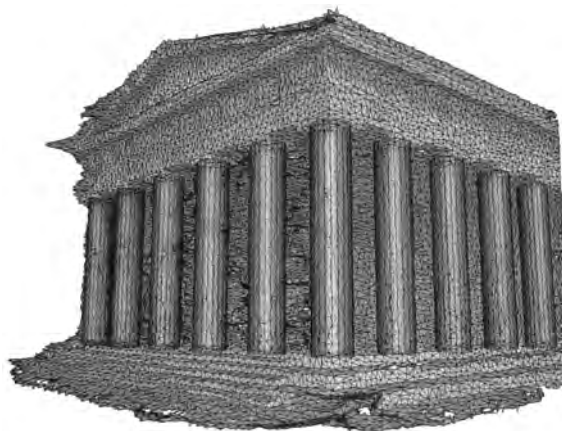


Figure 1: This is an example of a bad visualization. It shows the result of a reconstruction process: a Greek temple and its fitted reconstruction. The surfaces intersect, but based on this image it is not possible to examine the reconstruction's quality. Due to a missing legend no quantifiable error can be determined.

colors and color perception. Last but not least the application is embedded into a context.

Our algorithm calculates distances between dense samplings of geometric objects. Its main idea is based on the method for calculating errors between surfaces presented in *Metro: Measuring error on simplified surfaces* (Cignoni et al., 1998) and *MESH: Measuring Error between Surfaces using the Hausdorff distance* (Aspert et al., 2002). In order to speed up the calculation of a Hausdorff distance, which has a quadratic runtime in a naive implementation, the samples are stored in kd-trees (Gonnet and Baeza-Yates, 1991). The nearest-neighbor-search algorithm we use has an average runtime of  $n \cdot \log(n)$  and is described in *An introductory tutorial on kd-trees* (Moore, 1991).

Our algorithm to calculate normal distances (i.e. the nearest neighbor search restricted to points inside a double cone) is based on a commonly used grid structure. This technique can be found amongst others in (Farin et al., 2003) and (Hege and Polthier, 2002). Having calculated the distances our application offers predefined color palettes. The default color settings take the human perception and perceptual ordering into account. An overview on colors and color perception can be found in MAUREEN STONE's field guide to digital color (Stone, 2003). The set of predefined color maps contains the luminance-based maps with only small variations in the hue value as proposed in (Levkowitz and Herman, 1992) and in (Bergman et al., 1995) as well as the maps proposed in *Rainbow Color Map (Still) Considered Harmful* (Borland and Taylor II, 2007). The often used rainbow color map is available but not used as a default. The predefined color maps also contain neutral color settings. These settings do not have "signal colors" such as red. The selection of the neutral color ranges are based on *How NOT to lie with visualization* by (Rogowitz et al., 1996).

Visualizations of surfaces differences are needed in many fields, e.g. comparison of mesh reduction results (Klein et al., 1996). The main context, in which we use our application, is the field of cultural heritage. Especially for issues on scanning, fitting and reconstruction the application turns out to be a valuable tool. An overview on current research topics in cultural heritage can be found in (Baltsavias et al., 2006). As the program is not limited to this field of application, its context will not be discussed in detail here.

### 3. THEORY

This section describes the mathematical background for calculating a distance. Without loss of generality it is sufficient to consider point sets. Other geometric primitives can be converted into point sets by dense sampling.

#### 3.1 Metric

A nonnegative function

$$d : X \times X \rightarrow \mathcal{R}$$

describing the "distance" between neighboring points for a given set  $X$  is called a metric, if it satisfies

$$d(\vec{x}, \vec{x}) = 0 \text{ and } d(\vec{x}, \vec{y}) = 0 \Rightarrow \vec{x} = \vec{y} \quad (1)$$

as well as the symmetry condition

$$d(\vec{x}, \vec{y}) = d(\vec{y}, \vec{x}) \quad (2)$$

and the triangle inequality

$$d(\vec{x}, \vec{z}) \leq d(\vec{x}, \vec{y}) + d(\vec{y}, \vec{z}) \quad (3)$$

for all  $\vec{x}, \vec{y}, \vec{z} \in X$ . The most simple example which satisfies all conditions is the discrete metric

$$d(\vec{x}, \vec{y}) = \begin{cases} 1, & \vec{x} \neq \vec{y} \\ 0, & \vec{x} = \vec{y} \end{cases}$$

In the field of computer-aided design (CAD) and computer graphics the Euclidean metric is of particular importance. Two points  $\vec{x} = (x_1, \dots, x_n)$  and  $\vec{y} = (y_1, \dots, y_n)$  of an  $n$ -dimensional space have the Euclidean distance

$$d(\vec{x}, \vec{y}) = \sqrt{(x_1 - y_1)^2 + \dots + (x_n - y_n)^2}.$$

In some cases it is convenient to use the maximum metric

$$\mu(\vec{x}, \vec{y}) = \max(|x_1 - y_1|, \dots, |x_n - y_n|)$$

or the absolute value sum metric

$$\sigma(\vec{x}, \vec{y}) = |x_1 - y_1| + \dots + |x_n - y_n|.$$

The relationship between all these metrics in  $\mathcal{R}^n$  is given by the inequality

$$\forall \vec{x}, \vec{y} \in \mathcal{R}^n : d(\vec{x}, \vec{y}) \leq \sqrt{n} \cdot \mu(\vec{x}, \vec{y}) \leq \sqrt{n} \cdot \sigma(\vec{x}, \vec{y}) \leq n \cdot d(\vec{x}, \vec{y}).$$

The special case  $n = 1$  leads to

$$d(\vec{x}, \vec{y}) = \mu(\vec{x}, \vec{y}) = \sigma(\vec{x}, \vec{y}) = |\vec{x} - \vec{y}|.$$

#### 3.2 Point Sets

The distance between a single point  $\vec{x}$  and a point set  $Y$  can be defined using the minimum of all distances between  $\vec{x}$  and a point  $\vec{y} \in Y$ .

For two point sets there are many different ways to define the directed distance. DUBUISSON and JAIN have analyzed the following six distance functions (Dubuisson and Jain, 1994):

$$d_1(X, Y) = \min_{\vec{x} \in X} d(\vec{x}, Y) \quad (4)$$

$$d_2(X, Y) = K_{\vec{x} \in X}^{50} d(\vec{x}, Y) \quad (5)$$

$$d_3(X, Y) = K_{\vec{x} \in X}^{75} d(\vec{x}, Y) \quad (6)$$

$$d_4(X, Y) = K_{\vec{x} \in X}^{90} d(\vec{x}, Y) \quad (7)$$

$$d_5(X, Y) = \max_{\vec{x} \in X} d(\vec{x}, Y) \quad (8)$$

$$d_6(X, Y) = \frac{1}{||X||} \sum_{\vec{x} \in X} d(\vec{x}, Y) \quad (9)$$

where  $||X||$  is the number of elements in  $X$  and  $K_{\vec{x} \in X}^j$  represents the ranked distance; i.e.  $K_{\vec{x} \in X}^0$  corresponds to the minimum,  $K_{\vec{x} \in X}^{50}$  to the median and  $K_{\vec{x} \in X}^{100}$  to the maximum of all distances  $d(\vec{x}, Y)$ ,  $\forall \vec{x} \in X$ .

While it is sensible to use the minimum function for distances between a point and a point set, nested minimum functions ( $d_1$ ) do not define a meaningful distance between two point sets. All point sets  $X$  and  $Y$  with non-empty intersection would have a distance of zero. The oriented Hausdorff distance, named after FELIX HAUSDORFF (1868-1942), does a better job. Its definition ( $d_5$ ) utilizes the maximum function.

Oriented distances are characterized by  $d(X, Y) \neq d(Y, X)$  in most cases. Taking the maximum of both oriented distances leads to a *non-oriented* distance; e.g. the non-oriented Hausdorff distance between  $X$  to  $Y$  takes the maximum of both oriented distances:

$$H(X, Y) = \max(d_5(X, Y), d_5(Y, X)) \quad (10)$$

$$= \max \left( \max_{\vec{x} \in X} d(\vec{x}, Y), \max_{\vec{y} \in Y} d(\vec{y}, X) \right) \quad (11)$$

An illustrative example on Hausdorff calculations is shown in Figure 2.

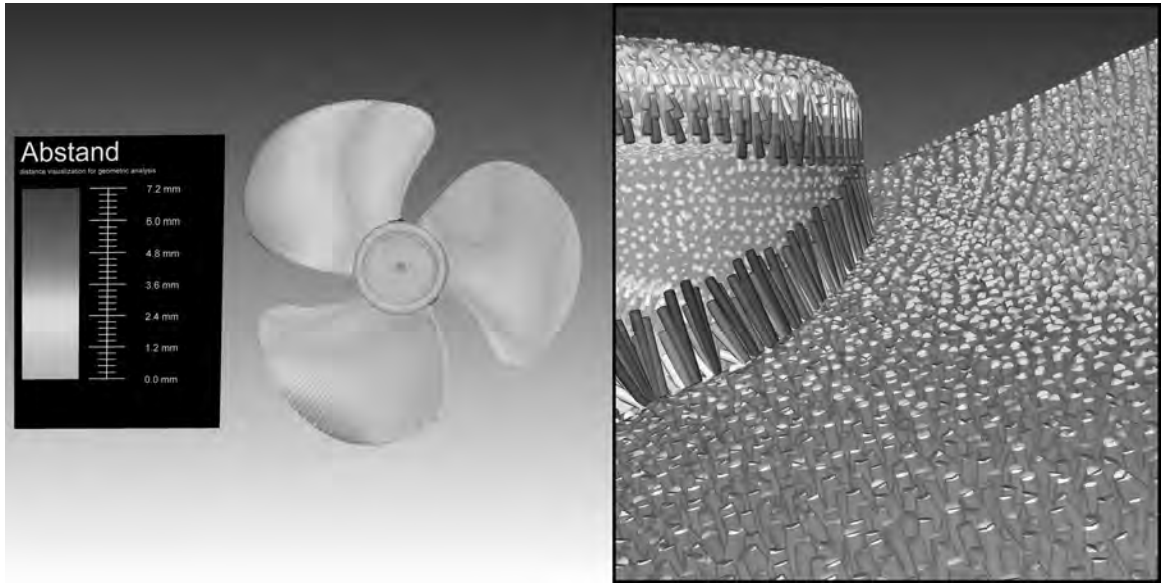


Figure 4: This example shows a laser scan of a propeller and its corresponding CAD model. The reference model has been reengineered based on measurements of the real object. Using this input data, the application ABSTAND calculates an appealing visualization. The scanned surface is colored according to the distances to the reference model. To have a clear look at the colored distance visuals, the reference model is almost transparent. For this example, only the one-sided distances from the actual model to the reference model are visualized using small, solid cylinders. The user can choose the number of distributed cylinders. The polygon count of the result can be limited to a desired, maximum number. According to these settings the quality/level-of-detail of the cylinders is determined.

The combination of the other distance functions ( $d_1, \dots, d_4, d_6$ ) results in

$$D_1(X, Y) = \max(d_1(X, Y), d_1(Y, X)) \quad (12)$$

$$D_2(X, Y) = \max(d_2(X, Y), d_2(Y, X)) \quad (13)$$

$$D_3(X, Y) = \max(d_3(X, Y), d_3(Y, X)) \quad (14)$$

$$D_4(X, Y) = \max(d_4(X, Y), d_4(Y, X)) \quad (15)$$

$$D_6(X, Y) = \max(d_6(X, Y), d_6(Y, X)) \quad (16)$$

Please note that these functions are not metrics in contrast to the Hausdorff distance.  $D_1, \dots, D_4$  do not fulfill the condition

$$D(X, Y) = 0 \Rightarrow X = Y,$$

which could be a problem for object matching.  $D_6$  violates the triangle inequality. Nevertheless,  $D_3, D_4$ , and  $D_6$  have some importance in the field of computer vision.

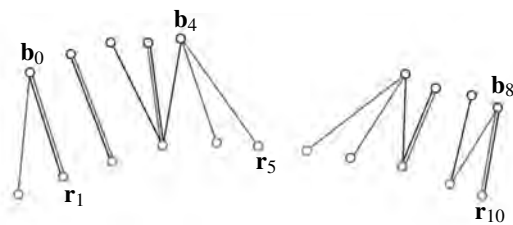


Figure 2: The Hausdorff metric defines the distance between two sets. For illustrative purposes each point of one set is connected in the same color with its nearest neighbor of the other set. The oriented Hausdorff distance from the blue points to the red ones can be found between  $b_0$  and  $r_1$  (longest blue line). The oriented Hausdorff distance from the red points to the blue ones is between  $r_5$  and  $b_4$  (longest red line). The maximum of both distances is the Hausdorff distance between these point sets.

### 3.3 Signed distance

A two-dimensional manifold object in  $\mathbb{R}^3$  defines an inner and an outer space. For geometric primitives, which form a two-dimensional manifold, it is convenient to indicate the location of a point in the sign of the measured distance. By convention points in outer space have positive distance, points in inner space have negative distance.

## 4. CLASSIFICATION AND ALGORITHMS

The main idea of the application is to classify the distance visualization problem into categories. Each category has a set of default settings which lead to feasible results.

### 4.1 Variance Analysis

All distance visualization problems belong to one of two distinct groups. The *asymmetric* case analyzes two geometric objects as-

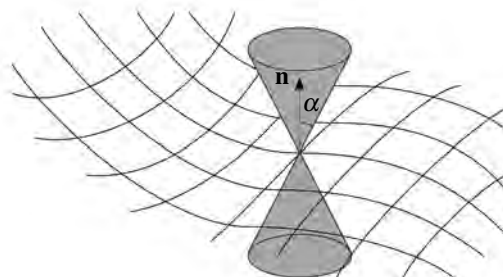


Figure 3: In some cases it is sensible to restrict the nearest-neighbor-search to samples inside a double cone along normal direction. Undesired sample relations at parts, which do not have a corresponding counter part, can be avoided.

suming that the first object is the reference / nominal object. The second object is the actual object to be validated. Such a configuration can be found e.g. in the context of quality management using a CAD model as reference to check the resulting product (see cathedral example in Section 6).

The *symmetric* case is characterized by the absence of a reference model. Both objects are on a par. In contrast to the asymmetric case the results of the symmetric one do not change, if the order of the imported objects is swapped. A typical, symmetric situation is the comparison of two range maps of a laser scanning process. If overlapping regions of aligned scans are analyzed, none of them can be considered to be the ground truth (see chess pieces scan examples in Section 6). These two main groups require different settings.

## 4.2 Symmetric Distance Visualization

The distance analysis starts by generating samples of both input objects and calculates their normals. Then the one-sided distances are computed and assigned to the samples. The nearest-neighbor-search can be restricted in two ways.

- For some cases it is useful to restrict the search area to a double cone along the normal as illustrated in Figure 3.
- Lower and/or upper bounds are another way to filter the results – for example ignoring all distances smaller than an epsilon.

The remaining distances are sorted and then grouped in a histogram according to their length.

For the two analyzed meshes, a unobtrusive coloring is suggested. The transparency value may vary according to the signed distance. This technique enables to display inner parts which would otherwise be covered by opaque surfaces.

Solid cylinders (or prisms with a lower polygon count) are generated to visualize the distances (see Figure 4). These distance visuals are grouped using the calculated histograms.

## 4.3 Asymmetric Distance Visualization

Calculations for the asymmetric case start similar to the symmetric one. But the results can also be limited to one-sided distances. As one surface is considered as ground truth, the visualization emphasizes the actual object. The reference object plays a minor role in the visualization. Its main purpose is to provide orientation in 3D – especially if the actual objects (e.g. scanned remains of a vase) are much smaller than the reference object. The actual object may also be colored according to the assigned distances.

## 4.4 Colors

The geometric objects / meshes as well as the distance visuals can easily be colored using preconfigured color scales. These schemes include color maps with good order properties in terms of human perception. Most of distance visualization schemes use luminance-based scales, for example the black-body radiation spectrum. For surfaces isoluminant color maps with opponent colors are suggested (see Figure 5). These surface colorizations do not compromise the depth perception. Neutral color tables are also available, if extra highlighting of differences is not desired. If the geometry is shown in a single color (with possibly varying transparency), the application proposes a color which does not belong to the color scale. Furthermore it automatically generates a legend in an appropriate range.

## 5. IMPLEMENTATION

All of the described algorithms have been implemented into the Java-based application ABSTAND. The stand-alone program can be downloaded or started via a web browser:

<http://www.cg.v.tugraz.at/Abstand>

The user only needs to provide two meshes to be analyzed.

### 5.1 File Format

For the input meshes and for the results of our application, a suitable file format is needed. There are too many “standard” formats for 3D data. The practical approach to this problem has been to look for a format that is widely used by common modeling applications and viewers. In this way, the import of geometry and further processing of the results is harmonized.

We use a subset of the 3D Object format (OBJ) introduced by Alias Wavefront. Coloring the results is done by a material file (MTL). In lack of per-vertex-colors, the material file stores a separate material for each color and transparency value. This subset ensures full compatibility to other applications.

The a generated legend can be included into the scene. Special care has been taken to ensure a correct rendering of the legend. Therefore, the captions are put on a texture template whereas the color scale itself is not part of the texture. It is built out of quads using the same material file and settings as used by the distance visuals. This approach ensures that the appearance of the colors is coherent. Different texture environments, which specify how texture values are interpreted when a fragment is textured, may otherwise lead to color discrepancies.

### 5.2 Usability

The visualization of distances can be done in various ways with many parameters. To have a useful and supportive tool, it is very important to have a good set of predefined parameters working out-of-the-box. Only by choosing a scenario based on the classification in 4.1 the application is able to automatically generate an appealing visualization. But tweaking of all the parameters is also possible in the advanced settings.



Figure 5: The color settings include color ranges, which take human perception into account; e.g. the Black-Body-Radiation scheme in the first row. According to BORLAND ET AL geometry should be drawn in an isoluminant scheme (second and third rows). The set of predefined color settings also contains some neutral color schemes, proposed by ROGOWITZ ET AL, as illustrated in the third row. It does not use “signal colors” such as red. Deceptive and misleading color ranges such as the rainbow color scheme (last row) are also included, as they are often used in wide-spread visualization systems.



### 5.3 Manifold Approximation using Normal Vectors

The normal vectors of the triangles are used to define half-spaces. With these half-spaces the inside and outside of the difference space in-between is defined. To work properly, the normals have to point outwards of tessellated objects. There is no way to determine correct inside and outside spaces fully automatically in all cases, especially for surfaces with holes. The distance calculation provides signed distances to each sample. Then it is possible to set the transparency according to the depth. The inside parts of a surface can be opaque and the outside parts transparent.

The distances can be visualized using simple cylindrical solids (or prisms with a lower polygon count). Using solids gives a more volumetric look than with lines. Furthermore, this representation is supported by almost all applications capable of importing OBJ files, while importing lines is only available in a small number of viewers.

### 5.4 Transparency

In most cases the visualization contains two surface layers. To show both objects it is necessary to use advanced techniques such as cut-away illustrations, which can hardly be made automatically and need special viewers, or adequately chosen transparency. In order to use conventional tools/viewers we chose an automatic approach based on transparencies.

While in general it is no problem to render still images with transparency, interactive display may not always render transparencies correctly. Correct rendering of transparent objects needs a back-to-front sorting of all surfaces. Special care has to be taken for interpenetrating objects.

To have an appealing visualization for the interactive rendering, we offer a transparency simulation by a varying wire frame representation. Each transparent triangle, for example, is replaced by three quads as shown in Figure 6. The area of the quads is inversely proportional to the triangle's transparency. For high transparency values, the quads almost form lines along the borders of the triangle. For low values, the triangle appears rather opaque leaving only a small hole in the middle of the face. This technique offers a comparable illustration in viewers, which do not render transparency correctly, at the expense of the polygon count.

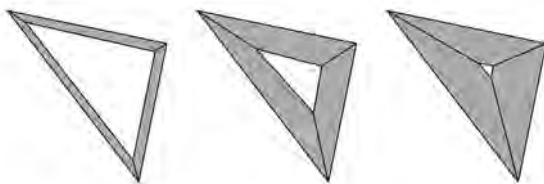


Figure 6: The overall transparency of a rendered object can be simulated by a varying wire frame representation. The area of the quads is inversely proportional to the triangle's transparency. This technique offers a comparable illustration in viewers, which do not render transparency correctly, at the expense of the polygon count.

## 6. EXAMPLES

The first example shows a result of the asymmetric preset of ABSTAND. It shows a data set of the Pisa Cathedral, which has been generated by the Visual Computing Laboratory at the Institute of Information Science and Technologies (ISTI) of the Italian National Research Council (CNR). The scan of the Duomo Pisa is compared to the results of an algorithm which identifies arcades automatically. The visualization – shown in Figure 7 – helps to verify the quality of the algorithm's output. Mismatching areas can be identified easily.

The second set of test objects demonstrates the symmetric case. It consists of two range maps from a laser scanner. The range maps have only a small area of overlap. Having set the upper bound of visualized distances slightly above the scanner's accuracy allows to concentrate on the alignment fit. Both objects have been acquired using a NextEngine™ laser scanner. Figure 8 shows a high-quality rendering of the resulting visualization. Furthermore a 3D representation is embedded in U3D format. Transparent faces are transformed according to the method described in 5.4 to ensure an appealing result independent of the capabilities of the U3D rendering plug-in. The Acrobat™ U3D plug-in allows to inspect the surfaces as well as the histogram structure of the distances. The predefined groups can be selected, marked and hidden using the plug-in's tree view.

## 7. CONCLUSION

We presented an out-of-the-box application to visualize distances between surfaces in an easy to use way. The proposed classification scheme is suitable to assign all surface comparison tasks to two main sets of default settings. Matching color tables are suggested automatically on a scientific basis.

By using a well established file format, the output files are harmonized with common 3D rendering tools and viewers. On the one hand the resulting files can be used to produce still images in the classic ray tracing fashion. For interactive illustrations on the other hand the application offers a technique to optimize the export settings to get appealing results. These optimized settings avoid irritating misinterpretations and visualization errors in different viewers. The overall work-flow to produce high-quality visualizations of distances between surfaces has been reduced significantly. Furthermore the application takes the latest results in human perception and visualization techniques into account.

Although the presented application offers many possibilities, sensible defaults allow an easy handling. The application is organized in a check list-like manner. Processing each point (choose distance function, select color scheme, etc.) step-by-step reduces the probability of many commonly made errors in diagrams (e.g. no legend included).

The application uses state-of-the-art algorithms to calculate the distances very fast, but in contrast to many other distance visualization programs it also concentrates on the resulting visualization: a clean representation of facts without overextending the observer. Last but not least, the application is based on web technologies and works out-of-the-box and does not need any configuration or installation:

<http://www.cg.v.tugraz.at/Abstand>

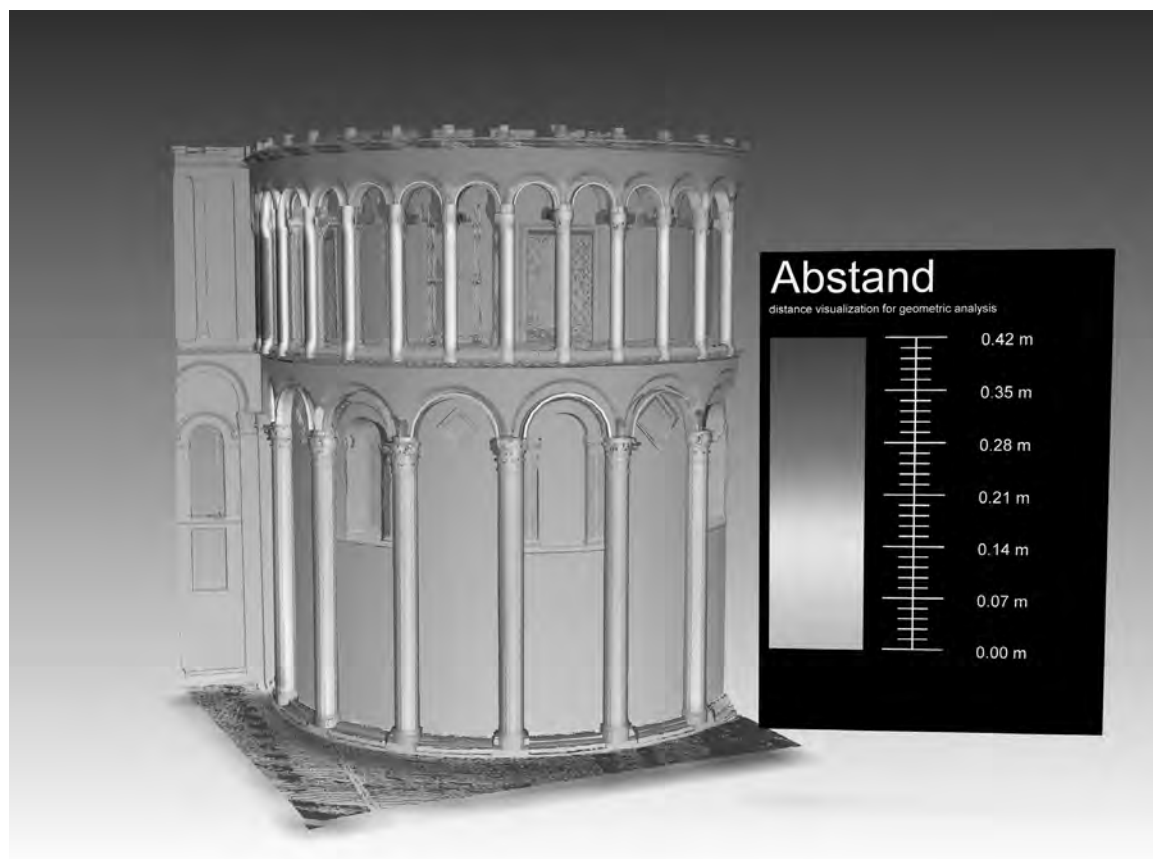


Figure 7: In an asymmetric configuration an actual/nominal comparison is visualized. The reference object is a laser scan of the Pisa Cathedral. Two fitted arcades have been determined by an algorithm. The difference between the scan and the automatically calculated surfaces describe the quality of the fit. Using ABSTAND these differences can be analyzed and visualized easily.

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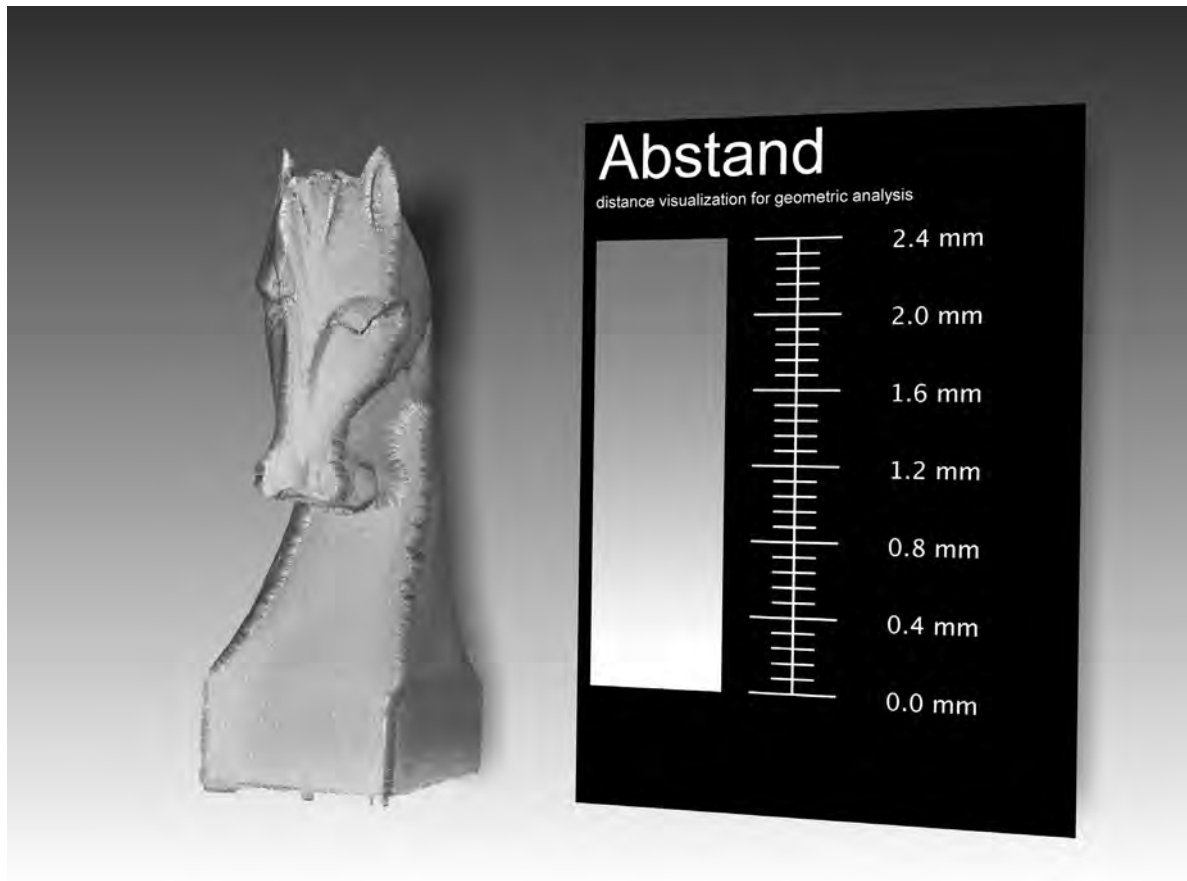


Figure 8: During the scanning process several range maps of a scanned object have to be aligned to each other. The presented application ABSTAND is able to create the visualizations that highlight the alignment fit. Having selected the class of settings only the range of distances to visualize has been adjusted to the accuracy of the scanner. The export routine has been harmonized with diverse tools to allow easy conversion – for example to U3D for PDF embedding.

**Please note:**

**This is a static preview. The interactive version can be found in the conference’s “additional material” section.  
The interactive rendering requires at least Acrobat Reader 8.**

## IMAGE-BASED CLASSIFICATION OF ANCIENT COINS

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**KEY WORDS:** Computer Vision, Numismatics, Classification, Optical Character Recognition, Local Image Features

### ABSTRACT:

*Numismatics* deals with various historical aspects of the phenomenon Money. Fundamental part of a numismatist's work is the classification of coins according to standard reference books. Reference numbers make the full description of a given coin type (including accurate dating, the distinction between minting places or any available political background) obtainable for everyone. The classification of ancient coins is a highly complex task that requires years of experience in the entire field of numismatics. *Computer Vision* explores the theory and technology to obtain and interpret information from images. For the application of ancient coin classification, image processing techniques like Image Enhancement, Image Segmentation, Pattern Classification and Optical Character Recognition (OCR) are investigated. The aim of the project is to develop a framework for image-based classification of ancient coins. The framework comprises the image acquisition step, where optimal conditions for the acquisitions of coins are examined. In the segmentation step image regions with arbitrary coin shapes are detected. And finally in the classification step, discriminative features like local image features and coin legends obtained by optical character recognition (OCR) methods are extracted from the images.

### 1. INTRODUCTION AND MOTIVATION

In this paper we present ILAC, a project in a interdisciplinary topic, Computer Vision together with Numismatics. Numismatics is at a point where it can benefit greatly from the application of computer vision methods, and in turn provides a large number of new, challenging and interesting conceptual problems and data for computer vision.

Numismatics deals with various historical aspects of the phenomenon *Money*. Among others, numismatics comprises the systematic research of minting plans, the distribution of coin finds, or the economic value of coinage. Fundamental part of the work is the classification of coins according to standard reference books. Reference numbers make the full description of a given coin type (including accurate dating, the distinction between minting places or any available political background) obtainable for everyone. Classifying ancient coins is a highly complex task that requires years of experience in the entire field of numismatics.

From its beginning in the late 7<sup>th</sup> century BC the minting of coins has always been a subject of mass production. In the antiquity and the Middle Ages the only devices for coin striking were hammer and anvil (see Figure 1).

The *hand crafted manufacture* of coin dies lasted into the 18<sup>th</sup> century AD. The die was not struck with the same force on every coin. Moreover, it was not centered with the same accuracy on the flan. Also the flans, the blank metal pieces, were hand-crafted and differ in size, shape and – most important – in weight. Furthermore, the coin die itself wears off by the time – it is estimated that the number of coins possibly struck from the same die can range up to between 5,000 or 10,000 (Duncan-Jones, 1994; Wolters, 1999). Despite the fact that several thousand coins could have been struck from the

same pair of coin dies, every single coin is an object with many individual features such as its weight, die-axe (orientation of obverse and reverse die relative to each other), fragmentations or even intentional alterations like cuts, graffiti or countermarks (see Figure 2).

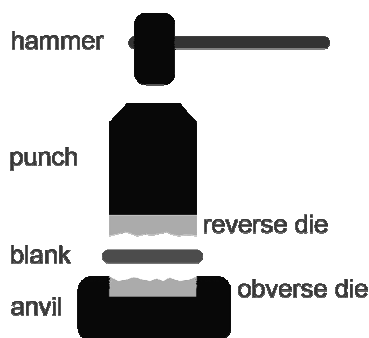


Figure 1: The striking of an ancient coin

The broad use of digital cameras has led to an exploding number of digitally recorded coins. While computers are extensively used for storing and working on numismatic data, no computer aided classification system for ancient coins, which is based on images, has been investigated so far. Digital images have become the usual way of exchanging information not only for internet auctions but also between scholars, collectors and coin dealers.

An automated image-based classification can be integrated into several different stages of the numismatic research:



Figure 2: Different coins of Antonius I.  
Pius struck for Diva Faustina I.

- *Portrait-based recognition of the issuers.* This is only feasible within periods with individual coin portraits (e.g. the Roman period between ca. 20 BC until the middle of the third century (Schmidt-Dick, 2002)).
- *Legend matching.* For the entire Roman period, coin legends are often of even greater relevance for the classification than pictures, so that matching of character recognition results to a list of possible legends will help a great deal. Determining reference numbers can only be achieved when the results of a method can be matched with a digital format of a standard reference. However, even if a method is not able to give a distinct reference number for each coin – be that in lack of numismatic information, poor preservation of the specimen, or insufficient matching – also to retrieve a certain probability for a portrait, a type, or a number is of great value since there is very often the need to classify large numbers of coins in a short time (e.g. with large hoard finds of more than 10,000 pieces).
- *Die identification.* The most advanced task to be achieved is to determine which coins were struck from the same die. Of course, the reliability of the results depends on the image quality but even a certain percentage of probability would mean a great help and also methodologically serve as a sort of proof since it can be repeated at leisure.

From image processing point of view various techniques and concepts are investigated for the application of ancient coin classification:

- In *Image Enhancement*, the goal is to accentuate given image features for subsequent analysis (Gonzalez & Woods, 2002). The enhancement process itself does not increase the inherent information content in the data. It simply emphasizes certain image characteristics. For the purpose of image-based recognition of ancient coins, image enhancement can be applied to overcome specific problems due to e.g. improper image acquisition. This includes – amongst others – contrast and edge enhancement, noise filtering, sharpening and magnifying of the original image data.
- *Image Segmentation* refers to the process of dividing an image into parts that have a strong correlation with objects or areas of the real world contained in the image (Pal & Pal, 1993). In general, object segmentation requires domain specific knowledge.

For our purpose an image segmentation algorithm has to robustly detect the image region showing the coin. As a preprocessing step, coin segmentation thereby provides a region-of-interest as a starting point for the classification process.

- *Pattern Classification* is the process of assigning data to predefined classes (Duda & Hart, 2000). Typically, the number of classes is known beforehand and can be derived from the problem specification. A set of elementary properties, called *features*, which describe some characteristics of the object, is chosen. In image-based classification of ancient coins, a classification covers the definition of a distinctive set of features, the extraction of those features from coin images and the assignment of a coin to known, predefined coin classes.
- *Optical Character Recognition (OCR)* is defined as the translation of written characters contained in images into an internal computer-usable representation (e.g. ASCII code) (Mori *et al.*, 1999). Regions, presumably containing circular text, are selected by examining the medium to high angular spectral bands of the coin, where the coin center is selected as the center of the angular discrete Fourier spectrum. An essential requirement for OCR lies in the development of an accurate recognition algorithm for the analysis and classification of digitized images into corresponding characters. The recognition algorithm has to be robust against variations in character typefaces, sizes and fonts. For the classification of ancient coins (especially for coins from the Roman period), coin legends are of great relevance (Schmidt-Dick, 2002). Thus, a reliable recognition of coin legends improves classification results to a high degree.

The remainder of this paper is organized as follows: Section 2 gives an overview about the state-of-the-art in image-based coin recognition. Project Aims are summarized in Section 3. The methodology intended to be used for coin classification is described in Section 4. Finally, a conclusion is given in Section 5.

## 2. STATE-OF-THE-ART

Recent research approaches for coin classification algorithms focus solely on modern coins. Applied pattern recognition algorithms are manifold ranging from neural networks (Fukumi *et al.*, 1992)(Bremananth *et al.*, 2005) to eigenspaces (Huber *et al.*, 2005), decision trees (Davidsson, 1996), edge detection and gradient directions (Nölle *et al.*, 2003)(Reisert *et al.*, 2006), selforganizing maps (Vassilas & Skourlas, 2006) and contour and texture features (van der Maaten & Postma, 2006).

Huber *et al.* present in (Huber *et al.*, 2005) a multistage classifier based on eigenspaces that is able to discriminate between hundreds of coin classes. The first step is the preprocessing performed to obtain translationally and rotationally invariant description. Due to the controlled setup of the system presented coin detection becomes a trivial task. Rotational invariance is obtained by estimation of the rotational angle. This involves cross-correlation of the coin presented to the system with reference images. Each reference image is associated with a coin class depending on thickness (estimated from additional thickness sensor measurement) and diameter. In the second stage an appropriate eigenspace is selected. Again,

based on the diameter and thickness measurements multiple eigenspaces are constructed. Thus, each eigenspace spans only a portion of the thickness/diameter plane and a moderate number of coin classes. In the last stage Bayesian fusion is applied to reach the final decision. Bayesian fusion incorporates probabilities for both obverse and reverse sides of the coin and knowledge about its orientation coherence. They report correct classification for 92.23% of all 11,949 coins in the sample set.

In (van der Maaten & Poon, 2006) a coin classification system based on *edge-based statistical features*, called COIN-O-MATIC, is presented. It was developed for the MUSCLE CIS Coin Competition 2006 (Nölle *et al.*, 2006) focusing on reliability and speed (see Figure 3 for example images). The system is subdivided into five stages: in the segmentation step (1) the coin is separated from the coin photograph. Next a feature extraction process measures edge-based statistical distributions (2). In order to give a good description of the distribution of edge pixels over a coin, they combine angular and distance information: edge distance measures the distance of edge pixels from the center of the coin and angular distance measures distribution of edge pixels in a coarsely discretized polar space. In the third step (3) – preselection – area and thickness measurement are used in order to obtain a reliable decision on the class of a coin. A 3-nearest neighbor approach on the two sides of the coin is applied (4). The last step (5) – verification – is only performed for coins for which the two coin sides were classified differently. It is based on mutual information of a test sample and an average coin image that corresponds to the classification assigned to the test sample. At the MUSCLE CIS Coin Competition the method achieved a recognition rate of 67.31% on a benchmark set of 10,000 coins.



Figure 3: Example images from MUSCLE CIS dataset

The *Dagobert* coin recognition system presented by Nölle *et al.* (Nölle *et al.*, 2003) aims at the fast classification of a large number of modern coins from more than 30 different currencies. In their system coin classification is accomplished by correlating the edge image of the coin with a preselected subset of master coins and finding the master coin with lowest distance. For the preselection of possible master coins three rotation-invariant visual features, besides sensor information of coin diameter and thickness, are used: edge-angle and edge-distance distributions similar to (Nölle *et al.*, 2006) and a third feature counting the occurrences of different rotation-invariant patterns on circles centered at edge pixels. In their experiments they achieved a recognition rate of 99.24% on a test set of 12,949 coins.

The coin classification method proposed by Reisert *et al.* (Reisert *et al.*, 2006) and presented at the MUSCLE CIS Coin competition 2006 (Nölle *et al.*, 2006) is based on *gradient information*. Similar to the work of (Nölle *et al.*, 2003) coins are classified by registering and comparing the coin with a

preselected subset of all reference coins. In the preselection step the radius of the segmented coin is determined and only coins with a similar radius are taken for comparison. The Registration and similarity computation of coin images is done by means of a Fast Fourier Transformation on binary images of discretized gradient directions. The final classification of a coin image is accomplished by a nearest neighbor scheme. The proposed method won the MUSCLE CIS Coin Competition 2006 with a recognition rate of 97.24% on a benchmark set of 10,000 coins.

Current research approaches for coin classification algorithms possess mainly two limitations. On the one hand, the input digital image is well defined – there is always only one coin pictured and the image is taken under very controlled conditions (such as background, illumination, etc.). On the other hand, current coin classification algorithms focus mainly on the recognition of modern coins. Those assumptions facilitate the classification process substantially. In this case of controlled conditions and the well known circular shape of modern coins, the process of coin detection and segmentation becomes an easier task. The almost arbitrary shape of an ancient coin narrows the amount of appropriate segmentation algorithms. A case in point is the segmentation approach based on the Generalized Hough Transform as proposed by (Reisert *et al.*, 2006). By definition, this method is only applicable for completely round coins. A segmentation through shape-adaptive thresholding is presented in (Zambanini & Kampel, 2008), showing a high robustness on coin images from various sources. However, varying conditions of image acquisition – e.g. illumination changes, multiple objects, multiple coins, varying background, etc. – remain the most challenging part of the segmentation process. Tests performed on image collections both of medieval and modern coins show that algorithms performing good on modern coins do not necessarily meet the requirements for classification of medieval ones (van der Maaten & Postma, 2006). The features that most influence the quality of recognition process are yet unexplored.

In February 2007, the EU-funded research project COINS (Zaharieva *et al.*, 2007) started, aiming at providing a substantial contribution to the fight against illegal trade and theft of ancient coins. One of its workpackages deals with image-based recognition of coins with main focus on the identification of coins, i.e. the recognition of individual features of a coin that permit to identify it uniquely as a predetermined one, whose features are known. Furthermore, the project will develop standardized inventories by defining a domain ontology and a multilingual thesaurus, data management tools and a specialized web search tool. The COINS project differs substantially in various aspects from this project:

- The COINS project addresses the traceability of stolen coins. Thus, it focuses on the *identification* of an individual coin based on peculiar features (e.g. minting signs or user-wear traces). By contrast, ILAC - the project presented - addresses the *classification* of ancient coins. There is an essential difference in the technologies applied. Identification relies on individual, unique features, which make a specimen different from all other individuals in the same class. Hence, an identification algorithm must ignore general features that are common to many individuals. On the contrary, classification emphasizes exactly those general features to assign an individual coin to a general category.

- The COINS project will develop documentation and inventory methodologies and tools based on international standards. Those *inventories* facilitate the interoperability and cross-border traceability of stolen coins. In ILAC, we aim to provide a *description language* to define the various coin classes of a given period. Such description language will guarantee required information for the classification process (e.g. legend description) and improve the interoperability between different numismatic databases.
- At last, the COINS project will provide a web search engine to enable the search for a known, stolen coin which is not a subject of the ILAC project.

### 3. PROJECT AIMS

The overall goal of the project is to develop a selection of methods for image-based classification of ancient coins. Up to now documentation and classification have been done manually which means a lot of routine work for numismatists and a very time consuming process for each object.

As a starting point, optimal conditions for the **acquisition** of coins have to be examined. In this regard, the technical competence of PRIP will be consolidated with the experience gathered by the numismatists. The effects on image quality due to acquisition are assumed to influence the performance of the segmentation and/or classification methods to a high degree. Therefore, a guideline for an optimal coin acquisition procedure has to be defined. This includes the description of the camera setup and optimal illumination conditions. Especially, the avoidance of shadows is an important issue since shadow casting at the coin border impedes the accurate detection of the coin by the segmentation algorithm.

A robust **segmentation** of the coin region is a necessary prerequisite for coin classification. Although an optimal image acquisition procedure will be defined, the developed methods are investigated on images from various sources, potentially originating from image acquisition setups where the illumination is not controlled. While performance deterioration due to uncontrolled coin acquisition will be unavoidable, robustness against image noise, inconsistent illumination conditions and shadows has to be provided. Additionally, the segmentation algorithm has to handle (nearly) arbitrary coin shapes. In contrast to modern coins, a perfect roundness of the coin can not be assumed which makes methods based on a circularity assumption, like the one presented in (Reisert *et al.*, 2006), inapplicable.

In the **classification** step, discriminative features have to be extracted from the images. For our purpose two basic types of features show a high potential for reliable differentiation of various coin classes: local image features and coin legends obtained by optical character recognition (OCR) methods. Discriminative descriptors of interest points, which allow for matching of characteristic coin patterns, have to be defined. Coin legends obtained by OCR provide important information as well. The high variability of coin legend characters and their arbitrary orientation impede the recognition process. However, the recognition even of legend parts may restrict the number of possible coin classes significantly. Since the number of classes to which a new one can be mapped is very high (e.g. (Schmidt-Dick, 2002) describes over 800 Roman coin types showing

solely female themes), a definite classification into one class will be impossible in many cases. Thus, the output of the classification procedure should be a list of possible classes with respective confidence measurement, supporting the expert in a fast categorization of coins.

As the goal of the project is a significant speed-up of ancient coin classification, the **processing time** of an automatic classification must be considered as an important issue. Therefore, an adequate tradeoff between high classification rate and short processing time is required.

Since images of coins have to be classified into pre-known classes, a database, that makes all necessary information (e.g. the ASCII text of the coin legend) available, has to be created. As described below in Section 4, coin types can be defined in different ways. Therefore, for the design of the database it has to be determined in which way coin classes are distinguished from each other. In other words, a **description language** defining the various coin classes of a period (e.g. the Roman period) has to be established.

### 4. METHODOLOGY

The classification process is like putting the objects through various sieves, from coarse to fine (Göbl, 1978, 1987). The scientific requirement is to give a coin its correct number in a reference book. There are different books for every period or every fraction of the monetary history – some covering several centuries and others only a few years of a single minting place.

A reference book does not cite single specimens of coins, but moreover *coin types* – a certain combination of pictures and inscriptions (see for example Figure 4). While some older books list all coin-types known to the author(s) in chronological order sorted by metal or even in the alphabetical order of their reverse legends, other books present the coins in the same pattern they were issued by the mint. During the Roman period groups of coin types can often be identified as being minted in the same production issue: a distinct group of coins was issued with a limited number of reverse types, covering several denominations (coin values), ranging from gold to brass-metal. In the coin production of the Celts no such sophisticated organization and administration ever existed, so that a Celtic “issue” needs to be defined differently. To sum up, the arrangement of coin types differs in the minting plan and consequently also in books. Reference literature also displays the state of research on a certain subject and consequently the quality of information gained from them varies considerably.



Figure 4: An example for the description of an Athenian tetradrachm of the 5th century BC

#### 4.1 Automatic Image-Based Classification of Coins

From image processing point of view coin classification process passes well-defined stages as shown in Figure 5.

In the *segmentation* stage an image is partitioned into its parts or objects. A robust segmentation is essential for imaging problems that require objects to be classified or identified individually. A weak segmentation algorithm causes the eventual failure of the whole classification process. In general, image segmentation algorithms follow three approaches. The first group partitions an image based on abrupt changes in the intensity (e.g. edges in an image (Heath *et al.*, 1998)). The second category identifies the image regions that are similar to a set of predefined criteria (e.g. threshold, color information (Liu & Yang, 1994; Shafarenko *et al.*, 1998)). The third group of segmentation techniques is based on finding regions directly (e.g. region splitting and merging (Hojjatoleslami & Kittler, 1998)). In the next step – *object detection* – the perceptually salient regions or objects are identified. In general, this process is based on predefined criteria ranging from simple measurements such as area dimensions or circularity to complex shape descriptors (Zhang & Lu, 2004). As output single or multiple objects that fit the criteria are identified for further processing. The goal of the *feature extraction* stage is to find those features that describe the object in a robust and compact way and provide optimal discriminative information. Choosing an appropriate set of features is critical for the classification process. Using a large number of features may better represent the object. However, the risk of overfitting arises since collecting a large amount of information can overfit the available training data and will not generalize well enough to it. On the other side, the selection of too few features decreases the separability of the object description. As a result, an object can be assigned to multiple classes. Ideally, for classification purposes, only those features are considered that are class-specific, i.e. with high separability and globalization power. Finally, in the *classification* step the extracted features are compared with the available training data. Current classification algorithms are manifold ranging from simple similarity measurements (e.g. Euclidean or Mahalanobis distances) to various statistical classifiers (Bayes, k-Nearest Neighbor, etc.) (Jain *et al.*, 2000) and approaches based on neural networks (Zhang, 2000). As result, a class membership is identified. Eventually, an additional *verification* step can assure the final decision of the classification process.

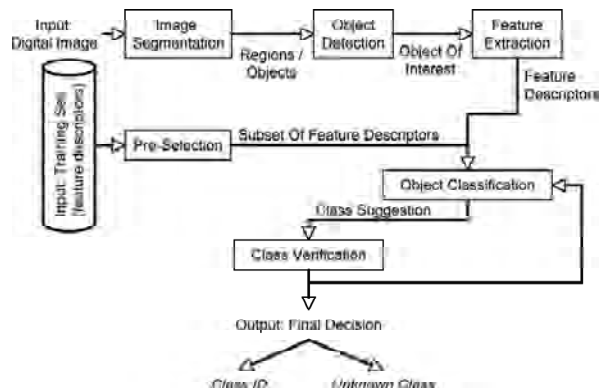


Figure 5: Coin classification process

For the special application of ancient coin classification, two types of features are expected to allow a reliable discrimination between coin classes: local image features and the coin legend provided by optical character recognition (OCR).

Local image features describe the image pattern in a window surrounding specific interest points and offer thereby a set of distinctive features for an image. Key issue in dealing with local points is that there may be large numbers of keypoints in each image which makes image matching more complicated. Typically, interest points are detected at multiple scales and are expected to capture essential features. An additional mechanism has to filter those points that are not stable or distinctive enough. An essential advantage of using local features is that they may be used to recognize an object despite significant clutter and occlusion. The Scale Invariant Feature Transform (SIFT) descriptor was first introduced by (Lowe, 2004) as a method for extracting local image features that are highly discriminative for object recognition. SIFT features are invariant to changes in image translation, scaling, and rotation and partially invariant to changes in illumination and affine distortion. Furthermore, they outperform further interest point descriptors such as steerable filters, differential invariants, complex filters, moment invariants, and cross-correlation (Mikolajczyk & Schmid, 2005).

Optical character recognition (OCR) in digital images has been extensively studied over the last decades (Mori *et al.*, 1999). In general, there are five major stages in the OCR problem: (1) preprocessing, (2) segmentation, (3) representation, (4) training and recognition and (5) postprocessing. *Preprocessing* includes the reduction of noise and normalization of the data, i.e. for coins the baseline extraction of the legend text, for instance by a transformation to polar coordinates. The *segmentation* stage has the goal to segment the individual characters on the coin. The *representation* step aims at both compact and characteristic description of the segmented characters. Many representation methods have been applied for OCR in the past including global transformations (e.g. moments (Chim *et al.*, 1999), wavelets (Shioyama *et al.*, 1998)), statistical representations (e.g. zoning (Takahashi, 1991), projections (Tao&Tang, 1999)) and geometrical or topological representations (e.g. geometrical properties (Oh & Suen, 1998), relational graphs (Li *et al.*, 1997)). For *training and recognition*, methodologies of pattern recognition are used to assign an unknown sample to a predefined class. Examples are elastic matching (Jain & Zongker, 1997), Hidden Markov Models (Mohamed & Gader, 2000) or neural networks (Hussain & Kabuka, 1994). In the



*postprocessing* stage, context and shape information is provided as feedback to the early stages of OCR for meaningful improvements in recognition rates. Thereby, context information is incorporated by spell checking and/or the use of a well-developed lexicon with a set of orthographic rules.

It must be noticed that a complete reliable recognition of the coin legends can not be assumed in many images due to abrasions on the coin and low contrast of the coin legend. However, even single characters or legend fragments can limit the number of possible reference coins. Figure 6 shows an example for legend segmentation of a modern coin.



Figure 6: Legend segmentation of a 25 Ptas coin from Spain

#### 4.2 Numismatists' Contribution to Classification

The tasks of the numismatist within the project are:

- Definition of the *manual classification workflow* as startup for the prototype of an automated classification algorithm.
- Create a *reference database* to which (images of) coins will be matched. Next to the image acquisition also digitalizing major parts of standard reference literature will be taken into consideration. This may result in an extensive modification of the structure of the most books. Reference literature is mostly not apt to be digitized without a great deal of further research or in-depth knowledge. The *definition of coin types* will turn out to be a crucial part – only then type lists can be created. Furthermore, lists of legends of both obverse and reverse and their possible combinations must be created, the same is required for portraits, reverse-pictures and by-marks. Also the “additional information” which is to be gained from classification needs to be included into the database. It is essential to ensure that the database can always be updated and enlarged according to the progress of current numismatic research.
- Ongoing *evaluation of the automated classification algorithm* to improve the results.

Starting point for an automated classification process would be the *recognition of the portraits* on the obverse side on coins from the Roman Empire (from its transition from Republic in BC 27 up to its reorganization under Diocletian in 294 AD, *principate*) since the number of persons having struck their

counterfeits on coins is limited. This is easier with coins in perfect conditions, the challenge lies in recognizing badly preserved specimens (see Figure 7). An accurate number of emperors on coins can always be disputed, because there are some family members – potential successors, children, wives, etc. – depicted, sometimes not even with their portrait but for example while horse-riding or mentioned in the coin-legends. However, from Augustus (BC 27 – 14 AD) until Aemilianus (253) there are 38 persons to be regarded as emperors. Including every individual person in every combination the number is likely to exceed 200. An example: quite a number of emperors strike coins for the dead Augustus, but the numismatic classification does not stop at the picture of Augustus, but always determines the actual issuer behind the coin.



Figure 7: Coins of Antonius Pius I. for his adopted son Marcus

Another promising starting point for an automated classification algorithm would be the *reverse-types* of the late Roman period from 294 AD, also known as *dominate*. In contrast to the principate, the number of different reverses is rather limited. Although the same types are struck by several emperors, the possible date of a coin can be narrowed down considerably by the mere recognition of the type – to establish the emperor himself can only be achieved by reading the legend, because there is nothing individual left about the portraits. Mint-marks can be ignored for that purpose – should they be clearly visible, they can be dealt with by OCR. For the very beginning the spectrum of reverse types can be narrowed down almost deliberately by time-spans, i.e. 294-498, 324-408 or 348-383, and later be widened.

## 5. CONCLUSION

In this paper the ILAC project was presented, an interdisciplinary project where Computer Vision methods are investigated to support and speed-up the classification process of coins shown in images. From a numismatists point of a view, an automated classification improves the efficiency of coin analysis and can be integrated into various research fields, like portrait-based recognition, legend matching and die identification.

The automated image-based classification is based on two major subfields of Computer Vision: Local Image Descriptors and Optical Character Recognition. For the first one reference images in a database are needed to which new coin images can be matched. The second one aims for the recognition of coin legends which give significant information for classification purposes.

Since a reference database is needed for an automatic classification algorithm, the main numismatic contribution to

the project is its definition and creation. This includes heavily the definition of coin types. Automatic coin classification relies on a categorization into definite classes which are currently not well defined in many cases.

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# EXPERIMENTING TIMELINES FOR ARTEFACTS ANALYSIS: FROM TIME DISTRIBUTION TO INFORMATION VISUALISATION

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**KEY WORDS:** chronology, timeline paradigm, information visualisation, interfaces, architectural changes.

## ABSTRACT:

When studying heritage artefacts, it is important to understand, communicate and cross-examine indications about how they evolved through time. Changes occurring in the artefact's morphology or functional role, once properly described and distributed in time, can be represented using linear graphics called timelines. Timelines have been, before and within the computer age, a classical and easy to understand visual support enabling the representation of a chronology, with in a number of examples a parallel reading of heterogeneous indications (historical context, cultural context, major dramatic events, etc.). In this paper, we first propose an overview of various types of timelines, applied to the analysis of architectural changes. We then introduce real-case experiments in which timelines are designed not only as a time-distribution representation, but also as information visualisation tools. The experimental set covers over 700 transformations within the urban centre of the city of Kraków. These experiments present the benefits of alternative graphic disposals that allow comparative and analytical readings of indications about artefacts changes, and can ultimately enhance information uncovering.

## 1. INTRODUCTION

### 1.1 The issue, the objective

When studying heritage artefacts, it is important to understand, communicate and cross-examine indications about how they evolved through time. Changes, if one reads them as consequences, imply that causes can be identified, and if not at least investigated. In other words, better understanding the evolution of artefacts though time can strongly benefit from trying to sort out indications we have for every relevant time slot, making clearer relations between possible causes (influences, events, etc.) and plausible consequences (architectural changes).

Changes occurring in the artefact's morphology or functional role once properly described and distributed in time, can be represented using linear graphics called timelines. Timelines have been, before and within the computer age, a classical and easy to understand visual support enabling the representation of chronologies. In a number of examples, they allow a parallel reading of heterogeneous indications (historical context, cultural context, major dramatic events, etc.).

But when looking at the very nature of the indications we handle when dealing with heritage architecture (uncertainties, lacking data, typology, duration, extent, causes of changes as far as architecture is concerned, etc.), there could be much more to timelines than a time-distribution of key moments and/or of indications. In short, when studying heritage architecture, we do not distribute in time "numbers" identifying key dates, but a set of complex, interpreted indications about changes.

This paper's claim is that, when dealing with heritage architecture, data can be distributed in time *using visual means*, and thereby fruitfully help understanding changes. E.R Tufte's masterpieces (Tufte, 2001, 2006a, 2006b) will convince anyone that *using vision to think* clearly applies to spatio-temporal data sets. And to architecture, specifically?

A number of solutions do exist, with some of the best dating back to XVIIIth or XIXth century with W.Playfair, E.J Marey or C.J Minard (pioneer of thematic cartography) presented in Tufte (2006a) or (Friendly, 2006). Do computers also help? In his analysis of Minard's contribution to statistical graphics, M.Friendly (Friendly, 1999) writes "*Minard almost invariably chose accuracy of data over the tyranny of precise geographical position when conflict arose*". In other words, it's the information that matters, not the mechanics or paradigm behind the representation. And so we will not focus on computer-based timelines only, although we will quote some of their pluses and minuses.

The aim of our contribution is to underline (through references to related work first, then through our own experiments) the variety of roles that timelines can have in fostering a better understanding of the evolution of architectural edifices or sites. We hope to demonstrate that beyond distributing items in a one axis visual disposal, timelines can also fruitfully act as:

- visual interfaces, allowing interaction with third-party data sets,
- interactive disposals allowing a time-based browsing of items,
- information visualisation disposals, with an aim to amplify cognition (Kienreich, 2006).

It is important to note once again that aiming at these goals raises specific challenges when dealing with architectural heritage information: long ranges of time, uncertainties in the dating, importance of cross-borders influences, difficulty to differentiate and classify changes (those with some kind of effect on the architecture itself, those that do not have immediate effect but will have, etc.). We do not pretend to provide answers and ready-to-use solutions to all these questions; however this paper should contribute to highlight a research issue needing further investigation. I.Johnson's *rethinking timelines* project has opened the way, highlighting this concern on a generic level. We believe that a specific

attention should be drawn on this issue in the field of heritage architecture.

## 1.2 Field of experimentation and structure of the paper

Since we have carried out investigations on the evolution of edifices in the urban centre of the city of Kraków for several years, we have chosen this test field in order to illustrate various real-case uses of timelines. We based this work on the observation that artefacts correspond to a sum of slots in space, and of slots in time. Consequently, we traditionally view artefacts as a sort of chain of items, with each item defined through a morphology (spatial identification) and a time slot. Each item can then be represented inside 2D/3D models corresponding to user chosen dates. But naturally, both the spatial and the temporal identification bears its uncertainties, due to the very nature of the information we handle (uncertain contradictory or lacking indications).

The experimental set covers over 700 transformations within the urban centre of the city of Kraków. All developments combine freeware technologies and standards web graphics (SVG/VRML).

In section 2, we propose an overview of various types of timelines, and further describe our field of experimentation in section 3. In section 4, we introduce chronologically a series of experiments we have had with designing dynamic timelines not only as a time-distribution representation, but also as information visualisation tools.

## 2. REPRESENTING EVENTS AND CHANGES USING TIMELINES: OVERVIEW AND CHALLENGES

### 2.1 Scope

A timeline is defined by the HarperCollins dictionary as a visual representation of a sequence of events, especially historical events. A wide attention is put on the issue of visualising time-related phenomena in the field of information visualisation (see for instance (Spence, 2001) or (Geroimenko, 2005)). As mentioned in (Dudek, 2007), a bridge can fruitfully be established between infovis practices and heritage architecture representation, not only as far as timelines are concerned. Still this discussion would go beyond the scope of this paper. Our presentation focuses on establishing roles and limitations of the solutions quoted, all of them using a straight linear metaphor (which is by itself a questionable choice, as mentioned in (Dürstener, 2006)). A number of resources about timelines can be found in (Friendly, 2007).

### 2.2 The basic timeline paradigm

**2.2.1 Distributing events:** Going through literature one can often find the word timeline used in naming what is in the end a list of dates, with only relevant dates shown. Naturally, we focus in this paper on visual timelines, and the above mentioned list-like visual disposal will be here named a “chronology” in order not to get confused.

Its graphic equivalent is the visual metaphor of a line, a classic and simple visual disposal where an axis represents the continuum of time. Along this axis, events and changes can be reported, although with a number of (often hidden) knowledge modelling issues (see Figure 1), in particular the time

granularity problem, and the uncertain/contradictory dating problem.

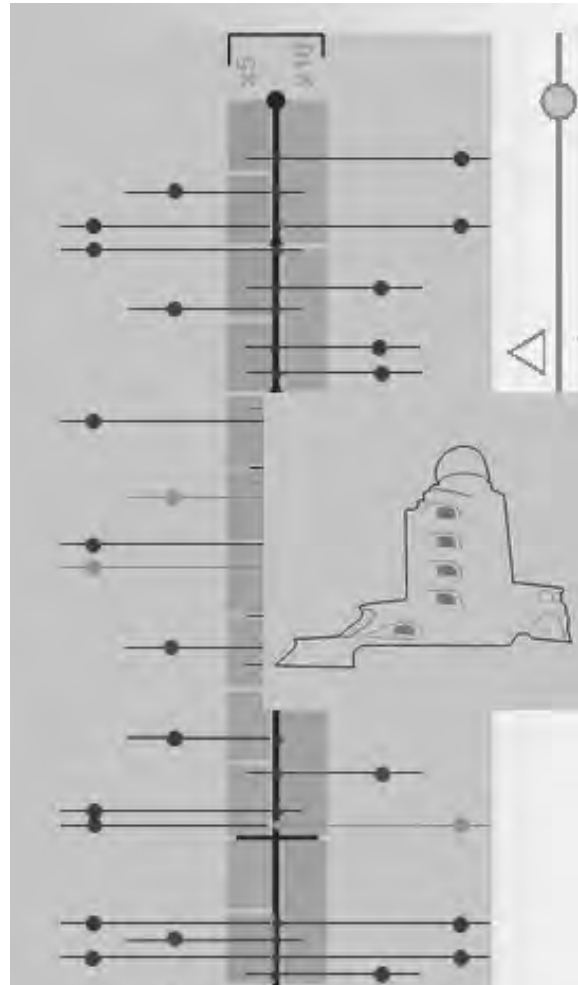


Figure 1: The UIA (International Union of Architects) XXth century architecture web repository timeline (A database of XXth century heritage edifices, [www.map.archi.fr/UIA](http://www.map.archi.fr/UIA)). Coloured lines and dots dispatched on the left and right sides of the line identify 48 reference buildings to which an edifice under scrutiny can be compared to (vertical line on the right). Brownish rectangles are used to query the database on 5 or 10 years intervals. The one year time granularity chosen here implies putting some reference buildings “on the same level” (coloured lines crossing the timeline), although several months can separate their construction.

**2.2.2 Distributing events and correlating them:** History is probably the domain where correlating events using a chronology has most widely been used. In the example shown in Figure 2, taken from the *civilisation of medieval occident*, a selected of so-called *facts* are correlated, in a list like manner.

A more visual example is given in Figure 3, in which (Koch, 1996) compares visually the periods covered by architectural styles in various European countries.

In these examples, the time axis acts as an integrator of events and / or changes, with variables expressed as parallel lines. In addition to knowledge modelling issues quoted in 2.2.1 (see for

instance in Figure 3 the author’s uneasiness with dating renaissance in France and Spain) such disposals introduce yet another challenge: finding the correct variables, and using a limited number of variables so as not to overload the graphics. (A graphic like this in Figure 3, established for the European union, would require 27 parallel lines. Anything readable then?). Furthermore, magnitudes of changes are hard to depict, and multivariate data cannot be handled properly.

DATES	FAITS MILITAIRES ET POLITIQUES	FAITS ÉCONOMIQUES ET SOCIAUX	FAITS RELIGIEUX
1257		1257. Bologne affaiblie sous les paiements des consules.	1257. Saint Bonaventure, un général de l'ordre franciscain. Échec des tentatives des séculiers pour élever les réguliers à l'université de Paris. Recluse de Sorbonne fondée à un collège pour théologie.
1258	1258. Evénement d'Orford.		
1259	1259. Traité de Paris : paix entre la France et l'Angleterre.		
1260	1360. Saint Louis intervient le dard judiciaire, le port d'armes et la guerre privée.	Apr. 1260. Le moulin à vent est d'usage courant en Occident. Entre 1260 et 1270, Étienne Belfère : Livre des Métiers de Paris.	
1261			
1262	1262. Partage du royaume d'Aragon : naissance du royaume de Majorque.		
1263		1263. Ecu d'or en France, 1263-1264. Pamoin en Bohême, Autriche, Hongrie, Sibérie.	1263. Émeute antijudaïque Cologne.

Figure 2: A partial view of (Le Goff, 1967) chronologic charts, with a classic correlation established between military and political facts, economic and social facts, and religious facts.

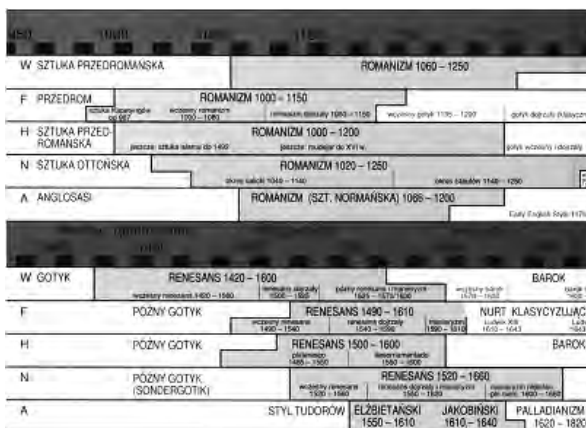


Figure 3: A partial view of (Koch, 1996) chronologic charts, focused here on the appearance of the renaissance style in Italy (line W), France (F), Spain (H), Germany (N) and England (A).

**2.2.3 Distributing and correlating events and periods, cross-examing information:** It is often necessary to distinguish events and changes with a short duration, as opposed to what we will call periods, with a long duration. Events and changes would then be depicted by visible, quantifiable results, whereas periods would serve as depicting the context leading or resulting from the events and changes.

In the example in Figure 4, symbols are used to mark events and changes (revolutionary outbreaks, constitution, intervention) whereas lines identify periods.

Another example are the generic timelines proposed by the MIT’s SIMILE project (Simile, 2008), a must in terms of technology, but a disposal that is based on the very same concepts.

Events and periods are distributed along an axis, with some interaction to allow querying of events reported. The limitations noted in 2.2.1 and 2.2.2 apply here as well.

In other words, it’s the mechanics or paradigm behind the representation that matters here, not the specificity of the information. This naturally raises an open debate.

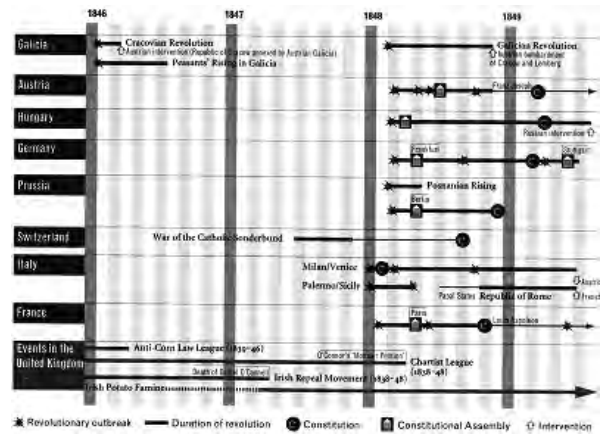


Figure 4: A brilliant visual comparison of revolutionary outbreaks in mid XIXth century by (Davies, 1997).

### 2.3 Timeline, timebands, time charts.

According to (Dürstener, 2006), a timeline is a one-dimensional graphic (with temporal flow depicted by a line), and a timeband is a two-dimensional graphic with one dimension used to represent time and the second to represent a magnitude associated to the events represented. Generalising even further, timebands / time charts may include in a two-dimensional graphics other variables, like in the splendid chart (Figure 5), taken from (Tuft 2006a) in which W.Playfair associated three variables (or time series) :

- price of wheat,
- weekly wages
- reigns of British Kings and Queens.

In this example, rules for reading the graphics remain simple: time flows from left to right along a line, although more information is available than in basic timelines. In other words, time charts do not imply a shift in paradigm, as examples in section 2.4 will.

Time charts are easy to read; they usefully enhance comparisons, cross examination of indications, and allow for magnitude assessment. However the design of efficient time bands or time charts is often neglected (and users of Gantt diagrams will for sure acknowledge they can be a dreadful bore).

Two challenges are raised: carefully choosing the relevant variables of course, but also organising to the best the representation itself. Tuft’s rules for graphic design (Tuft, 2006b) provide here a good methodological basis. Undoubtedly, the use of time bands and time charts could be more widely

developed in the field of architectural heritage information, as it is in the field of information visualisation.

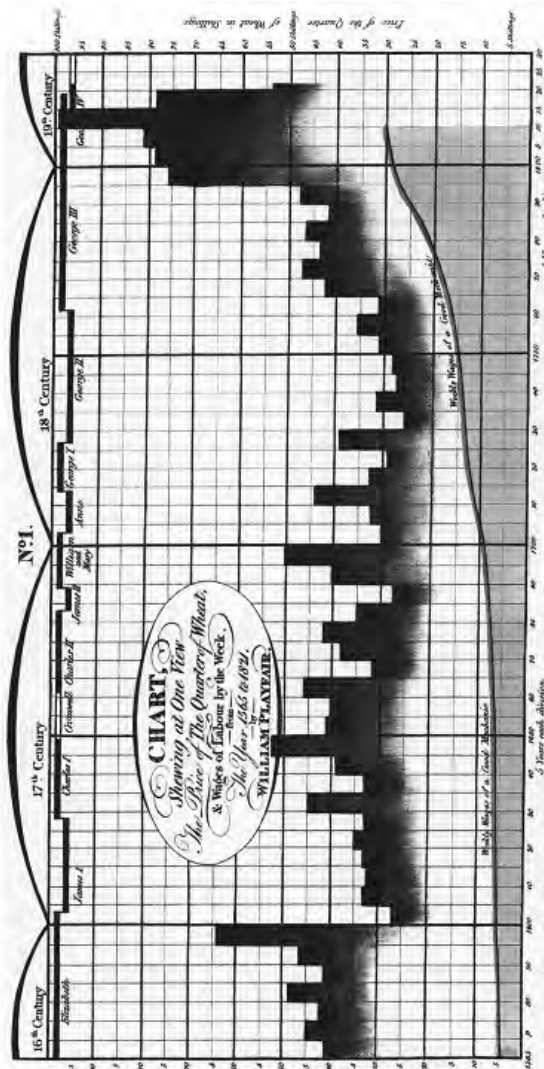


Figure 5: W. Playfair's time chart correlates three variables, observed through five years divisions, between 1565 and 1821. Blue curve: average wages, black polygons, price of a quarter of wheat, top line, King/Queen.

**2.4 Time distribution, and space: an open challenge**

Timelines (and related) have proven efficient solutions for chronology assessment and information correlation in various fields of experimentation, notably in history naturally. A number of researches are carried out in order to further develop them, to start with in the field of information visualisation.

Although this aspect goes a little beyond the scope of this paper, we would like to conclude this section by showing that the most complex and also challenging research issue is on how to better combine time+space representation. Readers will of course understand that when dealing with architecture, neglecting space is nonsense. But the concern we raise here also exists in other fields, and of course in history, as shown by the example in Figure 6. In this case too, the objective of the graphics is to provide indications on a chronology. But the shift

in paradigm is such that the reading of the graphics naturally over-emphasises the spatial nature of the phenomenon. Time is read once space is understood, and relative durations are hidden, with consequences on limits to the amount of variables that one can possibly handle, as clearly established by J. Bertin's graphic semiology (Bertin 1998).



Figure 6: Evolution of the polish borders under King Bolesaw Chrobry – with arrows marking movements. Understanding the chronology is less obvious than the spatial aspects. (Trąba, 2005).

Timelines are linear, and the succession of events is quasi-obvious. But when representing architectural changes over time using spatial representations (a constant concern since XIXth century authors major works on the history of architecture), time can only be represented using Bertin's graphic variables, and thereby cannot be easily read as a succession. The layer paradigm, implemented both in GIS platforms and in CAD tools, does provide a very basic mechanism that allows simulating successive states. But there is more to time passing by than a succession of layers; and concepts like magnitude or density of changes that one can handle layer by layer, cannot be chained in a single, time-based representation. In this convincing example below (Figure 7), a comparison is established between cities of the western provinces of the Islamic empire during the medieval period. Colour is used as the graphic variable representing time, and various symbols identify parameters observed (presence/absence of edifices, role of city). Although synthetic, and rich of information, the disposal can hardly compete with a timeline when trying to read a chronology.



Figure 7: An efficient spatial distribution, but a rather uneasy handling of time. How long does it take the reader to say which city was best developed during the XIIth century?. (from Encyclopedia Universalis – Le grand atlas de l'architecture mondiale, France 1998).

Pointed out by M.Friendly (Friendly, 1999), C.J Minard introduced yet another method of combining temporal and spatial data in a single graphics: the figurative maps.



Figure 8: C.J Minard figurative map showing losses in Hannibal's army during its trip from Spain to Italy .

C.J Minard's figurative maps can be understood as an interpretation of the concepts of ribbon maps, nicely described by I.Calvino as narrative maps. A well-known ancestor of ribbon maps is The Peutinger map of Roman routes, a map that has its equivalents in numerous societies across the planet, as demonstrated by I. Calvino (Calvino, 1998). Ribbon maps compel space to time: they represent in a 2D space the time needed to go from point A (x1,y1) to point B (x2,y2) with distance (A1,A2) representing a duration and not a length.

C.J Minard's figurative maps differ from basic ribbon maps in that a metric geography is respected, with a temporal, evolutive, ribbon-like phenomenon projected on this geography (see Figure 8). How to think out and implement efficient ribbon maps or figurative maps is undoubtedly today *terra incognita*, but could be a fruitful research direction. However this anticipates some of the concluding remarks of this paper.

### 3. FIELD OF EXPERIMENTATION

In the SIMILE project, a generic all-purpose timeline formalism is proposed. Why do we bother, then? Why do we believe this could be a questionable solution in our research context? Well, because our experiments on the city of Kraków have shown us that timelines may have different things to assess, and may require different visuals *displays of evidence* as E.R Tufte says it (Tufte, 1997). However the reader may not take this for granted. So, before presenting timelines themselves, we need to better present our field of experimentation.

#### 3.1 The city of Kraków

Former capital of Poland, the fourth largest city in Poland, Kraków has one of the best-preserved medieval city centres in Europe. The layout of the old town is a result of successive additions and of the evolution of various urban structures – initially the ensemble of the Wawel Hill, the suburbium called Okół and the medieval town located in 1257 (see Figure 9).

On the territory of the Unesco-listed part of the town a big number of architectural monuments remain, coming from all periods and styles from Middle Ages to the present. The urban layout of the city did not change a lot since the medieval period, although individual edifices may have been transformed. The area of the town is surrounded by a parkland green zone arranged in place of former fortifications (see Figure 10). The fortifications as well as trade buildings of the market square were victims of the XIXth century organisation and tidiness ideas. In 1684 forty-seven flanking towers were defending the town.

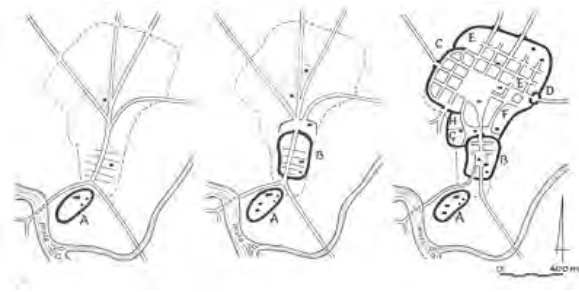


Figure 9: Kraków, the three earliest phases of urban structure's evolution (S. Bobiński, 1975).

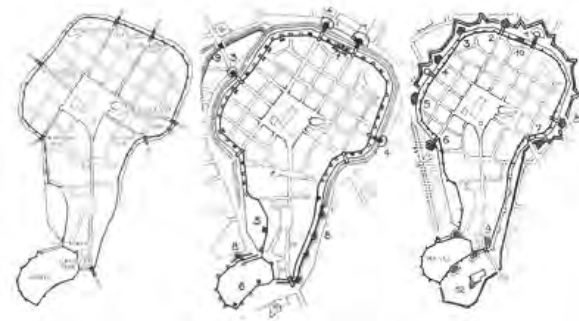


Figure 10: Kraków, development of the system of fortification – XIII/XV, XV/XVI, XVII according to (Bogdanowski, 1977)

Years of conservation actions, examinations and research conducted in this place produced a very significant quantity of various documents (descriptions, analyses, drawings, photographs, maps, reconstructive hypothesis, paintings, ...) that should be gathered, organised and visualised. Naturally, analysing and understanding artefact changes in such a context requires the cross-examination of various indications, and sources. It is clear that in the case of Kraków the risk is to become unable to sort out and interpret usefully sources.

And so the challenge here is to retain through visual means the artefact's documentation analysis, and provide graphic tools to reveal it. As demonstrated in J.Bertin's "graphic semiology" (Bertin, 98), attempting to exploit the spatial distribution of data sets raises numerous methodological questions about the efficiency and the readability of graphics. In response, we have tried to adapt ideas and methods from the field of information visualisation to the architectural heritage, where in addition the uncertainty of the sources handled poses specific problems (Dudek, 2007). But attempting to exploit the time distribution of data sets is also a challenge, and this contribution shows where we stand in developing graphics for representing time, and where we stand in connecting them with spatial representations.

#### 3.2 Method and objectives of our investigations

We consider that the best way to visualise, access and analyse the data related to the architectural and urban heritage is to use architecture itself as a mean to interface pieces of information, (see Dudek, 2007b). Our investigations therefore base on the premise that shapes act as a media allowing the integration of the above mentioned heterogeneous clues. Consequently, they may enable information visualisation and retrieval through 2D/3D dynamic graphics. Such clues, in other words the



artefact's documentation, vary in type and relevance, and are clearly at the heart of any historical investigation about artefacts changes. They are notably used in order to understand their morphological evolution, and can help researchers to represent its successive spatial configurations. In order to do so, an analysis of the documentation is carried out that helps putting in relation pieces of architecture at various scales (from details to edifices) and pieces of information. This naturally opens an opportunity to use the artefact's representation as a mean to retrieve/visualise information, as shown in (Dudek, 2007b).

It has to be stressed that, in any investigation of an historic artefact, the analysis of sources is duly done by scientists. Therefore the method presented here is not about going through sources in order to establish a document(s) <-> artefact(s) relation, but to retain this existing work, and to give tools to visualise it. This is done by handling four sets of tools/formalisms/data sets:

- An architectural ontology (implemented as a set of classes in the sense of OOP) handles the artefact's morphology. Each class is given methods that enable the instance to represent itself in SVG/VRML or to write an XML record file storing its morphological description. Various evolutions of an artefact are represented as a chain of instances, allowing the system to handle morphological and documentary changes through time.
- A relational database (VIA) stores for each instance descriptive criteria such as typological specificities or alternative denomination, with a focus on the representation of levels of certainty (to which extent can we say this artefact was there at that time? Who said so? Is this author credible?)
- A relational database (SOL) stores data about documentation and archival documents (traditional editorial details, physical format, etc.) This first level of description of the documents bases on the Dublin Core recommendation. More important here, each document can be connected to one or several instances of the VIA DB, allowing cross-querying of DBs.
- A set of classes (in the sense of OOP) produces in real time the graphics needed to represent the artefact at any time of its evolution. They output web-enabled formats, XML/XSLT, SVG, VRML. These graphics, may they be 3D or 2D (see Dudek, 2005), are therefore supposed to help users cross-examine the various pieces of knowledge they handle.

During these investigations, both architectural and urban elements of the town's construction, their evolutions (897 evolutions of 385 objects) as well as related historical sources (791 sources) have been described. These numbers remain very little compared to other experiments, or to the city itself. However they imply that we picture our work not only as putting studies one next to the other, but as handling individuals on one hand, and handling a collection on the other hand.

In other words, with such a number of edifices and sources, it becomes necessary to try and get an overall view of changes, and more globally provide means for context assessment. A collection of items becomes more than the addition of its components if it provides its own set of information. Accordingly, dealing with such a collection opens an opportunity to try and uncover new information by proposing

efficient comparative disposals. And this is where a variety of timelines, as will be shown, have been considered as necessary.

## 4. FROM TIMELINES TO INFOVIS

### 4.1 The first disposals

When we started studying Kraków's urban centre and its development, we soon faced the necessity to show how the morphology of edifices changes through time. Accordingly, we developed an ad-hoc timeline, nested as an interactive command inside 3D VRML scenes. This timeline, shown on Figure 11, allows users to move to and fro the foundation of the city interactively, with each element in the 3D scene modified accordingly. The content of the scene is itself a user selection.

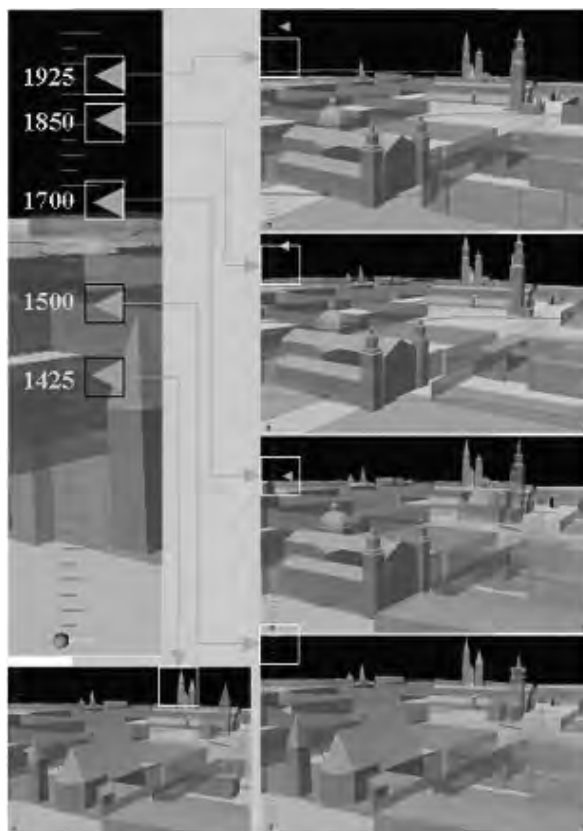


Figure 11: Screen captures of five moments in the development of the city, with in the foreground the noticeable change of orientation of Saint Anne Church. Note, left, the timeline itself, a basic one if any.

Besides a time granularity problem (one year intervals only), this disposal left us unsatisfied, since it allowed only a strict sequential browsing (no comparison possible between evolution 1 and evolution 5 for instance). It in fact did not much more than underlining what we already knew. So another disposal was tested, still in connection with a spatial representation: an interactive cumulative representation of changes (Figure 12).

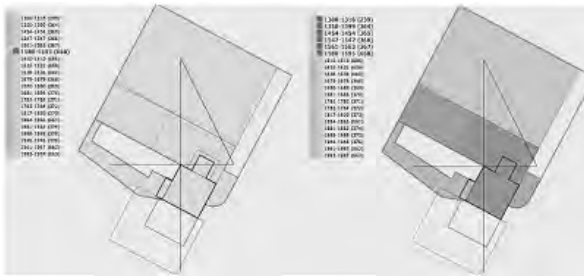


Figure 12: An SVG cumulative representation of changes on the case of Krakow's old town hall: left, the user selected period of foundation and contemporary period, right, the user selected all changes during the renaissance period.

## 4.2 One step beyond: an infovis perspective

### 4.2.1 Correlating architectural changes and level of documentation:

The documentation's analysis helps researches justify choices they make when describing how an artefact evolved throughout its history. It is therefore most important to find visuals means to put in parallel the chronology of evolution of the artefact, and the chronology of the sources in order to track lacks (i.e. moments of the artefact's history for which we can find no relevant source).

In the recent experiment shown on Figure 13, we developed a timeline that for each object under scrutiny allows the user to compare on two parallel lines :

- the periods of change of the object,
- the amount and periods of relevance of documents about those changes.

The timeline acts as a user-monitored layer on top of a 2D spatial representation of instances, dynamically produced in SVG. The timeline is linked with two other disposals, a certainty assessment wheel and a visualisation of documents types (differentiating books, maps, etc.).

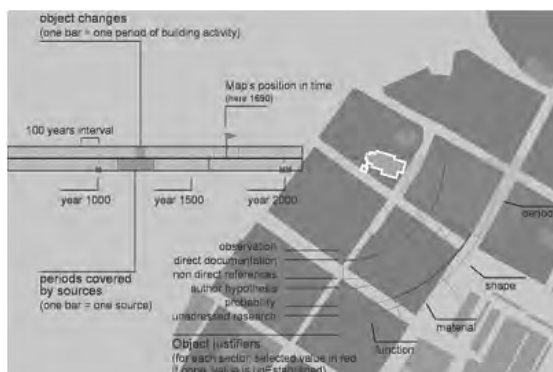


Figure 13: Legend of elements of the disposal. Note, (bottom part of the timeline) the dark grey, rectangles correspond to periods of relevance of documents; (top part of the timeline) rectangles correspond to object's transformations. On this rather simple object, correlation is good for the first period of changes, but poor for the two next.

### 4.2.2 Visualising densities of changes:

Once a collection of objects has been studied, it becomes possible to try and point out patterns of evolution, notably in order to underline moments of strong changes vs moments of relative stability, or in order to underline differences in the density of changes of various types of objects. Accordingly, we have an implementation of the above principle, shown in Figure 14 and 15, where each period of change for each object in the user's selection is represented by a horizontal gradation on the global vertical timeline.

This disposal's first objective is to allow a visual investigation of densities of changes. But it can also be used in order to mark differences between types, and thereby uncover different patterns of evolution. Although this disposal is somehow questionable from the point of view of readability (especially when reproduced on a sheet of paper like here), it clearly goes one step beyond our initial experiments with timelines. In line with an information visualisation perspective, it acts as a tool for thinking, uncovering new information.

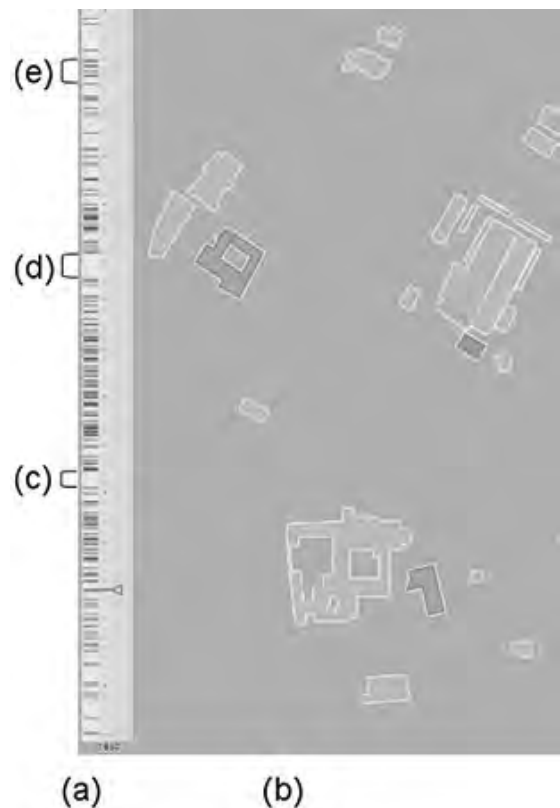


Figure 14: (a) the timeline itself, with its interactive triangular cursor (here on year 1850); (b) the user's selection (main edifices) are shown in their evolution for that period. Note questions raised by reading densities of changes, (c) a remarkable absence of transformations for monumental edifices between 1725 and 1745, most likely due to a succession crisis and a related war; (d) same absence of between 1500 and 1530, less easy to explain, thereby opening a question for interpreters; (e) an early and strong period of transformations, under the influence of Czech kings reigning in Poland at that time.

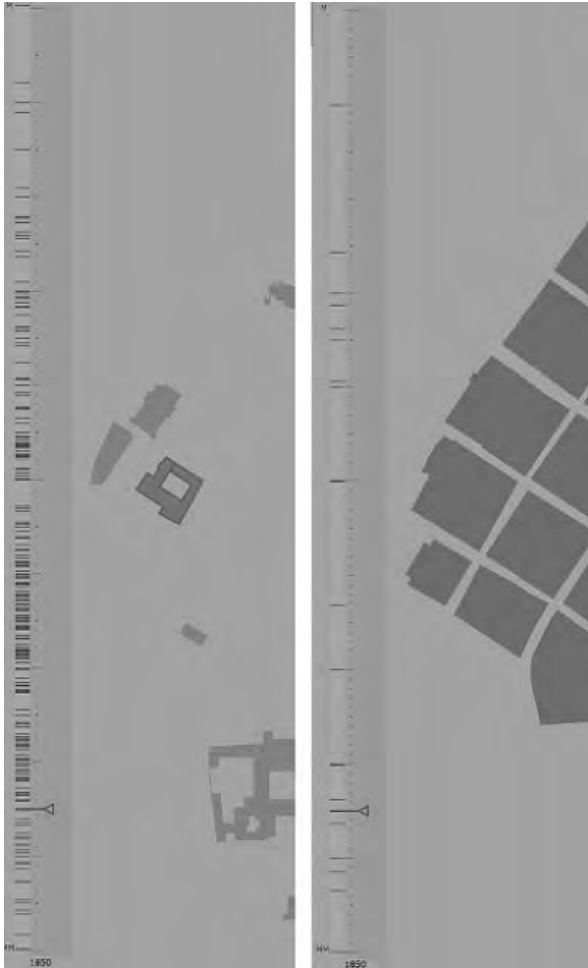


Figure 15: A timeline and an information visualization disposal. Each horizontal bar corresponds to a change in one individual inside the collection. The arrow is an interactive cursor monitoring the content of the 2D map (orange lines mark periods the user has not yet visualised). Note differences in densities of changes between, left, density of changes of major architectural edifices and, right, of urban blocks.

## 5. CONCLUSION

Researchers and practitioners can today fruitfully use basic timelines, that have proven efficient (notably because of a very limited cognitive load for users). But, surprisingly, very few fundamentally new visual disposals have been designed since the Information Technologies shift that would better match the reality of heritage investigations.

Indeed, the adoption new visual disposals as “tools for thinking about chronologies” implies tackling several issues: enabling variable granularity of time scales, reading densities through time distribution, representing lacking/questionable indications, cross-examining changes inside semantically consistent sets of artefacts, combining the reading of individuals and of collections, etc. And our contribution does not pretend to cover all these issues. It however shows that, if designed in an information visualisation perspective, they can go beyond distributing events in time, and provide grounds for information uncovering. Accordingly, although the results presented here

remain early stage results, they show it can be worth further investigating time visualisation methods and formalisms, in particular when working in historic sciences.

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## X-RAY CT: A POWERFUL ANALYSIS TOOL FOR ASSESSING THE INTERNAL STRUCTURE OF VALUABLE OBJECTS AND FOR CONSTRUCTING A 3D DATABASE

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**KEY WORDS:** X-rays, tomography, repairing, museum objects, natural building stone, 3D database

### ABSTRACT:

To obtain meaningful information on important museum objects, X-ray computed tomography (CT) can be applied. CT is an excellent non-destructive research tool: it can be used for a broad range of different materials while it contributes to the characterization of the internal structure of the object. As an X-ray beam passes through an object, the beam intensity decreases due to absorption and scattering. Mapping the variation of X-ray attenuation within this object allows a 3D reconstruction to be made. This paper presents the results of a structural investigation conducted on museum objects and important natural building stones by showing images obtained through X-ray radiography and computed tomography. Research on the internal structure and features of those objects provide the opportunity to visualize possible repairing interactions performed on these objects. It also generates an informative and educative advantage. By constructing a digital 3D database afterwards, the rendered volume can be shown in the museum together with the original object. Ultra valuable objects can reveal their internal structure to the audience without being cut. Additionally, 3D visualisations of different rock types, used in buildings of historical interest, were analyzed. Knowledge of their internal structure is of crucial importance for the maintenance and restoration of our Historic Heritage. This paper demonstrates that X-ray CT can be a powerful tool to investigate our Cultural Heritage in a non-destructive way.

### 1. INTRODUCTION

Computer tomography (CT) in general - using any kind of penetrating radiation - investigates the external and internal structure of objects in 3D, without actually opening or cutting. Without any form of sample preparation it is possible to obtain a 3D computer model of the sample within minutes. The technique has been a very revolutionary procedure in medical diagnostics, since it has enabled doctors to view internal organs and bone structure with precision and highly safety to the patient. It soon became clear that X-ray CT had a large potential by which the technique rapidly evolved and numerous non-medical applications appeared. Recently, X-ray tomography has become an important non-destructive tool in other fields too (Cnudde et al., 2006). It is used in biology, paleontology, sedimentology, archeology, soil science and fluid-flow research.

This paper is a presentation of a structural investigation performed on three bronze museum artefacts, a nautilus shell and natural building stone, showing images obtained by X-ray CT and X-ray radiography. Those three totally different types of material lend themselves extremely well for this non-destructive technique. It is known that for the research on bronze objects, computer tomography is performed on large installations such as accelerators and reactors providing either neutron beams or monochromatic X-ray radiation. The research aim of this paper was to see if a flexible, compact X-ray tube on the one hand is sufficient to penetrate bronze objects with a certain thickness, and on the other hand can operate as a non-destructive 3D capture technique for our Cultural Heritage. During this research, it was also explored if repairing interactions on bronze objects were detectable. Already in the seventies and eighties, computed

tomography was recognized by some archaeologists and museum curators as an efficient tool for non-destructive studying of archaeological artefacts, like Ancient Egyptian Mummies (Harwood-Nash, 1979; Derek, 1986; Pahl, 1986).

CT could also generate an informative and educative advantage, by constructing a database with the 3D volume rendered objects. Valuable museum artefacts, such as the three bronze objects from a Belgian collection and originally from South-China (Yunnan Province) and Vietnam (Dong Son Culture), can reveal their structure and possible repairing interaction to the audience without cutting it. Fragile objects with a remarkable internal fabric, like the nautilus shell, can be displayed in a museum together with the 3D rendered volume, projected on a screen. Visitors can now virtually cut through the object to gain information and to explore the unrevealed internal features. X-ray CT 3D numerical models of the scanned sample can be obtained for virtual reality applications and galleries or digital archive storages.

In addition, X-ray CT was applied on natural building stones for investigating the pore space distribution. Limestone has been a traditional building stone worldwide for centuries and is still used for this purpose today. Several buildings of historical interest are build up by this stone. Knowledge of such materials is of crucial importance for the conservation of our cultural heritage. For instance, the cause of stone degradation depends on its characteristics (internal factors) and the environment (external factors) to which it has been exposed. Freeze-thaw cycles, biological activity and interaction with acid rain mainly proceed in the pore space and the pre-existing (micro) cracks. The resistance to frost action depends on the porosity and especially

on the interconnectivity of the pores. If the pores are connected (open porosity), water inside the stone can quickly flow outside, creating minimal damage to the internal structure. A well-founded know-how of the different geological parameters is crucial for the study of restoration materials and CT turned out to be a good technique for this problem (Cnudde et al., 2004).

## 2. BASIC PRINCIPLES OF X-RAY CT

An X-ray micro CT scanner contains basically a fixed X-ray source, a rotational stage and detector (figure 1.). To perform CT, digital radiographs of the sample are made from different orientations by rotating the sample along the scan axis from 0 to 360 degrees. In only one radiography, the information of the sample is summed along the rays of the X-ray beam. This can reveal certain information, but to obtain a full 3D image of the sample, it has to be illuminated from different angles. Theoretically, the number of projections or radiographs necessary to reconstruct the internal structure of the object, is the product of the number of horizontal detector pixels and  $\pi$  (Kak et al., 2001). In practice, a number of projections roughly equal to the number of horizontal pixels is sufficient for a good acquisition. After collecting all the projection data, the reconstruction process is started, which produces horizontal cross-sections of the sample, allowing rendering 3D models. Materials like plastic, wood, polymers with light elements, and even denser objects like sediments and stone can be easily studied with X-rays.

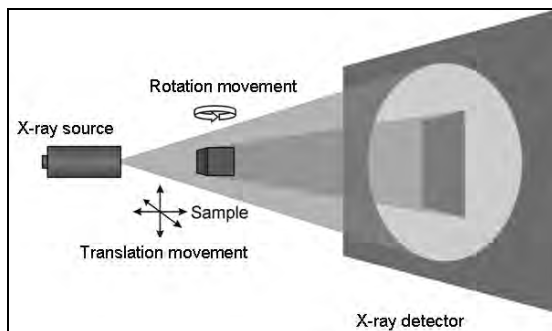


Figure 1. Typical set-up for an X-ray CT system

The physical parameter, providing the structural information, is the (X-ray) attenuation coefficient  $\mu$ . This coefficient is the product of the photon mass attenuation coefficient  $\mu/\rho$  ( $\text{cm}^2/\text{g}$ ) and the chemical density  $\rho$  ( $\text{g}/\text{cm}^3$ ) of the sample. The attenuation coefficient  $\mu$  depends on the local composition of the material of the sample. Furthermore, the mass attenuation coefficient depends on the energy of the X-rays: the higher the energy of the photon, the smaller the attenuation in the sample (for energies typically below 200 keV, where the photo-electric effect is the predominant process of interaction). X-ray CT is based on the X-ray transmission information and follows the Lambert-Beer equation (1):

$$I = I_0 \cdot \exp\left(-\int_L \mu(s) \cdot \rho(s) \cdot ds\right) \quad (1)$$

with  $I_0$  the X-ray intensity before passing through the sample,  $I$  the intensity after passing through the sample and  $L$  the path of the X-ray through the sample (typically a line between the X-ray source and the detector pixel).

It is well known that the attenuation of X-rays is strongly increasing with higher mass numbers of the investigated material. Therefore, in material research of bronze samples, the penetration of X-rays is limited and thick heavy metals of even a few mm can already attenuate the entire X-ray beam intensity. Also dens minerals inside natural building stones, e.g. biotite or hematite, can strongly attenuate X-rays passing through the object. Resulting star artefacts, radiation scattering and beam hardening effects (Ketcham & Carlson, 2001) can strongly limit the performance of the CT technique by means of a compact X-ray CT source, applied on materials with heavy atomic numbers such as bronze and stone. The resolution we obtain depends on the resolution of the detector, the spot size of the X-ray source and the magnification. The latter depends on the biggest diameter of the sample. In case of the natural building stone (diameter of 8 mm) we obtain a resolution around  $10 \mu\text{m}$ .

As X-ray source for CT, a synchrotron with a parallel, mono-energetic beam or a compact X-ray tube, with a polychromatic cone beam can be used. Synchrotron radiation has the advantage of providing a very large X-ray flux, which can be quasi-monochromatic and/or mono-chromatised using crystals. The monochromaticity also results in fewer artefacts in the reconstructed slices. Different X-ray energies are absorbed to a different extent, resulting in non-linearities and so-called beam hardening artefacts when a polychromatic beam is used. Although synchrotron radiation presents clear advantages over X-ray tube radiation, X-ray tubes are much more available and at a significant lower cost.

X-ray detectors are used to record the attenuation information along lines through the object, according to equation (1). To detect the transmitted X-rays they have to be converted to visible light with scintillation materials like Gadox P43 or CsI crystals. The visible light from the scintillator is in turn registered by CCD cameras, CMOS-flat panels or amorphous Si-flat panels. Direct conversion detectors, like photon counting solid state arrays or amorphous Se, are still not often used but could be the future for micro-CT.

## 3. INSTRUMENTATION AND MATERIALS

### 3.1 Instrumentation

The experiments were carried out at the Centre for X-ray CT at the Ghent University (Belgium). At the Centre, which is a cooperation between the Radiation Physics research group (Department for Subatomic and Radiation Physics, Ghent University) and the Sedimentary Geology and Engineering Geology research group (Department for Geology and Soil Science, Ghent University), a new high-resolution CT set-up was built, providing a high range of scanning possibilities. Formerly a desktop CT scanner, Skyscan 1072, was used to perform X-ray micro-CT scans at the Centre and although this is a very powerful tool, higher resolution and more flexibility were demanded. Therefore a multidisciplinary X-ray CT scanner was built inside a shielded room with a maximum flexibility. The X-ray tube of this high-resolution CT scanner is a state-of-the-art open-type device with dual head (Feinfocus®, FXE-160.51): one head for high power micro-CT and one for sub-micro- or nano-CT. An important advantage of this scanner is that different detectors can be used to optimize the scanning conditions of the investigated objects. This entire set-up is built on an optical table to obtain high precision.

Due to the dual head of the X-ray tube and the flexibility of the detector, the highest quality and the best signal-to-noise images for each type of sample are possible. For this research, the high power directional head was used as X-ray source. This head can produce a voltage between 10-160 kV, but for the bronze objects a voltage of 140 kV up to 160 kV with a power of 30 W and an Al-filter was chosen. Stone samples were scanned between 130 kV and 140 kV with an Al-filter, to block the low energetic X-rays. A high frame averaging from 30 up to 60 frames was selected and 400 projections were made for the bronze material. The total scanning time was 60 minutes. As X-ray detector, an image intensifier was coupled to a Sensicam camera. The sensor consists of 1280 by 1024 pixels, with a pixel size of 6.7  $\mu\text{m}$  by 6.7  $\mu\text{m}$ . The corresponding pixel size on the scintillator screen was equal to 140 by 140  $\mu\text{m}$ .

The CT data is processed with the in-house developed reconstruction software Octopus (<http://www.xraylab.com>). The raw projection data from the X-ray cameras are filtered by removing bright and dark spots, corrected for geometrical distortion of the image intensifier, normalized and regrouped in sinogram files, which are finally used to calculate cross sections (Vlassenbroeck et al., 2007). For 3D volume rendering, VGStudioMax 1.2 from Volume Graphics (64 bit version) was used. The software package consists of a series of tools to make movies and to virtually cut the object in all directions. Analyses and quantification of the porosity and mineral distribution in natural building stone are done with Morpho+. Thresholding and measurement of maximum opening, equivalent diameter and porosity are some of the main tools of the in-house made software program. The processing time depends on many factors, including the resolution. In case of the bronze objects and the natural building stone it took only 15 min to obtain our 3D image.

### 3.2 Materials

**3.2.1 A bronze cow:** The bronze cow (figure 2.a), with a size of 8 cm by 10 cm by 4 cm, is most likely a kind of totem. A totem is any natural or supernatural being or animal which watches over or assists a group of people, such as a family, clan or tribe, and it is to support larger groups than the individual person. The bronze cow originates from the Yunnan Province (South-China) and is most likely from the third century BC.

**3.2.2 A bronze anklet:** The bronze bracelet (figure 3.a), size 15 cm, is a beautiful ornament from the Dong Son culture. In the Dong Son culture, there were bracelets and tintinnabula-adorned wrist shields and anklets. Each wrist shield was provided with as many as fourteen of these tiny spherical bells and each anklet, with six. Tintinnabula were also found on the handle of one bronze ladle. In several points, those bronze artefacts were similar to those found in Yunnan, China, and in Indonesia.

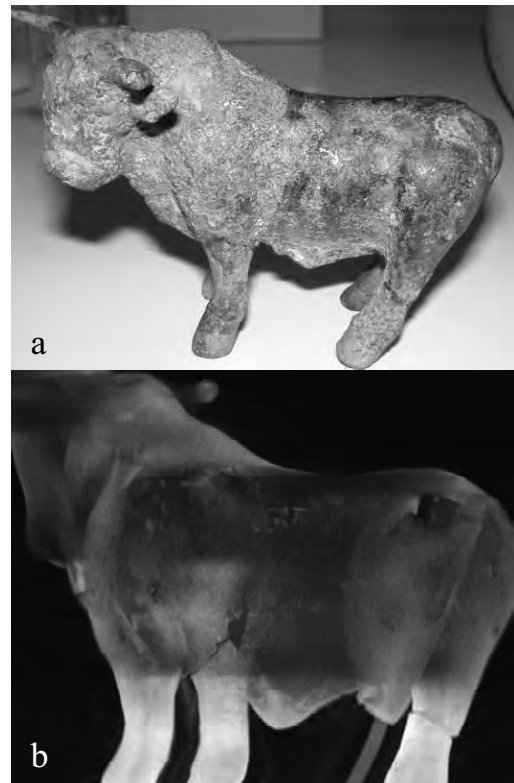


Figure 2. Photograph of the bronze cow (a), rendered model (b)

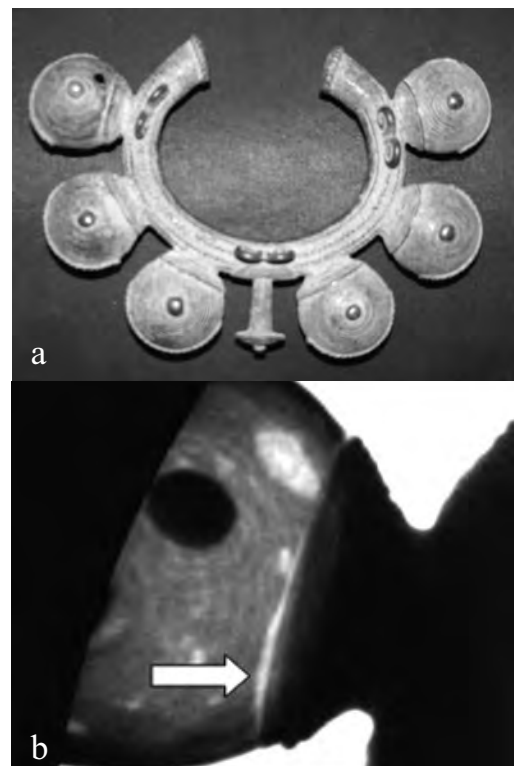


Figure 3. Photo of the bracelet (a), Detail of a radiograph of the scanned bronze bracelet (b)

**3.2.3 A bronze knife:** The bronze knife (figure 4.a, b), with a length of 25 cm, belongs to the Dong Son culture (1000 BC to 1 BC), a prehistoric Bronze Age culture that was centered at the Red River Valley of Vietnam. In 1924, a considerable number of graves packed with burial gifts were discovered in the Vietnamese village Dong Son in the Tonkin plains, not far from the city Thanh Hoa. In the next decennia, similar diggings across North and Central Vietnam lead to similar finds. Particularly striking was the level of bronze-casting of this prehistoric culture that was called after the place of the first excavation. The artefacts, discovered in the 1920s, were categorized as made by the 'Dong Son civilization' by Austrian archaeologist R. Heine Geldern in 1934, a term he used for all Bronze Age communities in Yunnan (China), Indochina and Indonesia.



Figure 4. Photo of the bronze knife of the Dong Son culture (a), (b); 3D rendered models (c)

The Dong Son culture spread from its centre along the middle reaches of the Red River to the Quang region, southwards past Cloud Col and northwards past the Dongtin Lake, reaching Yunnan, Guangdong and Guanxi in China. The use of bronze in the region of what is today Northern Vietnam, probably goes back to the 15th or 14th century BC, when archaic communities slowly developed into hierarchic societies. The Dong Son bronzes are mostly weapons, jewellery, utensils and ritual objects. Dong Son bronze objects are generally decorated with geometric patterns and figurative images. The abstract patterns are usually crosses, waves, cable-, comb- and tooth-motifs (Rawson, 1967).

**3.2.4 Natural building stone:** All monuments built with natural building stones are affected by weathering and controlled by the interaction between the stone itself and external factors. Also internal components, such as oxidation of iron bearing minerals can play a part in the weathering process. Physical, biological and chemical weathering processes proceed in the pore space and contribute to the disintegration of the stone. The existence of micro-cracks and anomalous cavities also control the weathering pattern of the stone. The Noyant Fine limestone is a beige-white natural building stone, used for in- and outside applications. It consists of fossilised biogenic organisms, such as gastropods, bivalves and foraminifera, connected within lime rich cement. The Noyant Fine limestone, exploited in France in the commune of Noyant and Aconin (5 km to the south of Soissons), can be used as restoration stone for different buildings of historical interest. A cylindrical sub-sample with a diameter of 8 mm has been scanned (figure 5) to visualise and analyse the pore size distribution and interconnectivity.

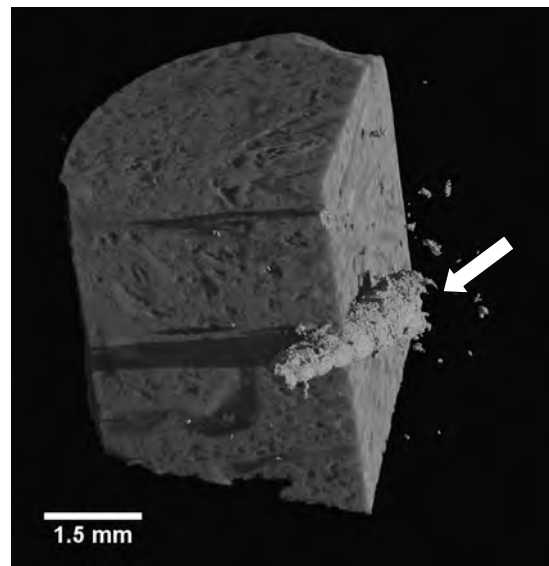


Figure 5. 3D rendered volume of the Noyant Fine building stone, visualization of a secondary pore structure

**3.2.5 Nautilus:** Nautilus is a common name of a marine animal of the cephalopod family. The animals 'bone structure' is externalized as a calcareous shell. The animal can withdraw completely into its shell by closing the opening with two specially formed tentacles. The shell is divided into chambers and the diameter is about 17 cm (figure 6.a, c).

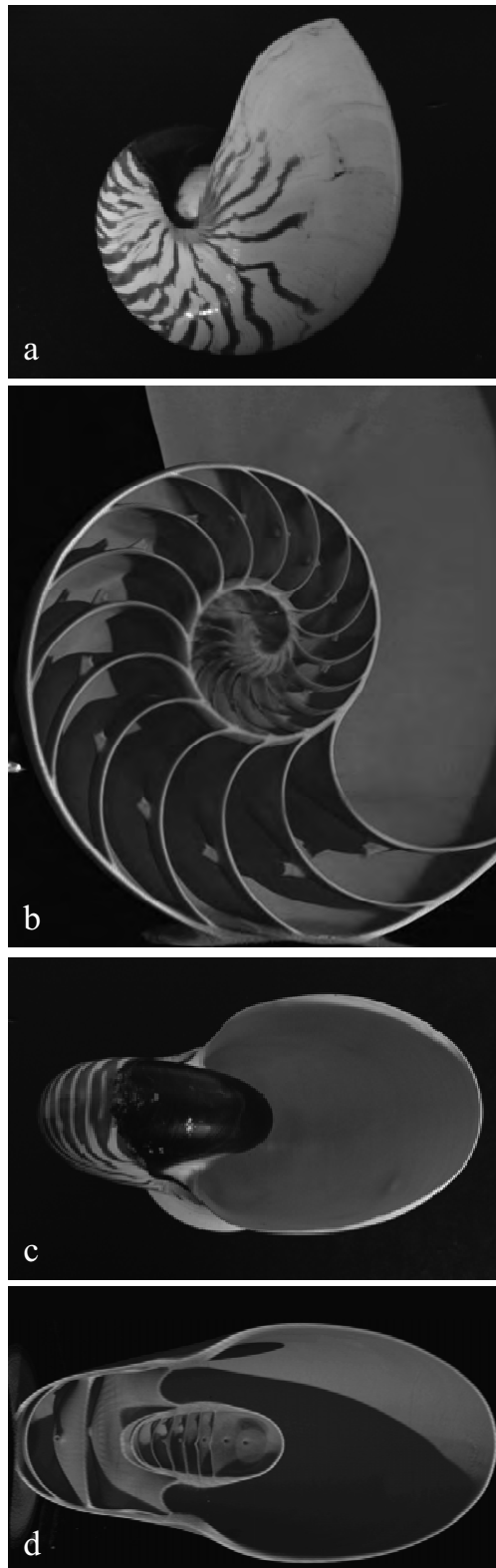


Figure 6. Photographs of the nautilus shell (a), (c); 3D rendered volumes (b), (d)

#### 4. EXPERIMENTAL DATA AND RESULTS

Although X-ray computed tomography presents different advantages over individual X-ray radiographies, radiographies can already reveal under certain circumstances a lot of information about the investigated sample. They can suffice for the identification of clear features in the bronze objects. It also has to be noted that the scans of the bronze objects performed with the current set-up presented severe beam hardening artifacts due to the combination of polychromatic radiation and the strong absorption of the dense and thick objects. This still allows us to render the surface of the reconstructed volume, but only limited information about the internal features and/or defects can be obtained. There is a clear need for higher energy X-rays to reduce this problem. One possibility is to use X-ray tubes with a higher voltage. It might however be even more important to use a detector more sensitive to high X-ray energies, since producing higher energy X-rays is not beneficial if they can not be detected. Because of these considerations, the presented results of the bronze artefacts are a combination of X-ray radiographs and CT scans.

The radiographs and the rendered volume (figure 2.b) of the bronze cow immediately revealed repairing of the bronze. Both back legs and one front leg of the cow were broken. The front leg and one of the back legs were re-attached later, while the other back leg was replaced by another material than bronze. The low attenuations of the x-rays prove that this replaced leg is made out of a material with a lower atomic number than bronze. The leg is fixed onto the cow, by a denser bar in the centre. Additionally, holes inside the body of the cow can be detected and those are again filled with not so dense material. No discontinuities were detected on the head, the ears, the horns or the tail, revealing that those pieces belong to the original cow.

Radiographs were taken of the bronze anklet (figure 3.b). A repairing interaction of one of the spherical balls could be detected. The white arrow indicates the less dense repairing material. Additionally, it was found that one of the internal balls, inside the spherical balls, was hollow, while the others were all filled. This hollow ball is probably also originally belonging to the anklet.

From the images of the bronze knife, it was uncertain if the statue of the woman was originally attached to the knife. The tomography of the bronze knife reveals a clear interaction of restores. The arms, legs and head covering of the woman were clearly restored due to the visible discontinuities inside the object (figure 4.c). Like in case of the cow, the restoration material that was used is less dense than the original bronze object. In order to reveal whether the woman was originally attached to the knife, analyses on the composition of both bronze pieces need to be performed.

Concerning the natural building stone, it was also possible to obtain 3D information from the 2D reconstructed slices. The in-house made software package Morpho+ first segments the image to select the objects of interest. In this case the pores inside the Noyant Fine limestone were segmented and labelled. A segmentation step converts a volume of gray scaled voxels into a set of objects. The pores inside the natural building stone have similar gray values and thus can be segmented as one object. Afterwards all the different pores are labelled, whereupon quantitative 3D interpretation, such as equivalent diameter, pore volume and interconnectivity, can be performed. From the literature it's known that the porosity of the limestone



amounts around 35 %. Our analysis on a volume of 115 mm<sup>3</sup> shows that the limestone consist of 14 % pores. Although those two values are different, they might be consistent. The scan was performed with a resolution of 9.5 µm, so smaller pores can't be visualized. The limestone is also heterogeneous, in such a way that a small sub-sample may not be representative for the whole rock. The pore distribution has been analyzed and divided into four main categories: 14 % of the pores has an equivalent diameter between 0 and 266 µm; 9 % between 266 and 532 µm; 15 % between 532 and 1.3 mm and one pore occupies a volume of 62 % with an equivalent diameter of 2.6 mm. The fact that there is one large pore could indicate that some micro-pores are interconnected and form one large unit. If the latter is true the form of the large unit should be very irregular, due to the connections between the pores. The calculation of the ratio between the equivalent diameter and the maximum opening of the large unit turned out to be almost equal to 1, which proves that the volume is almost spherical. The large unit is thus a single pore and there is nearly no interconnectivity larger than 9.5 µm between the pores. As the 3D rendered volumes show, most of the pores of the Noyant Fine limestone originated from the dissolution of biogenic fragments (figure 7). Figure 5 shows an isolated secondary pore structure, originated of the dissolution from a gastropode. In VGStudioMax the pore structure can be separated from the limestone as seen in figure 8.

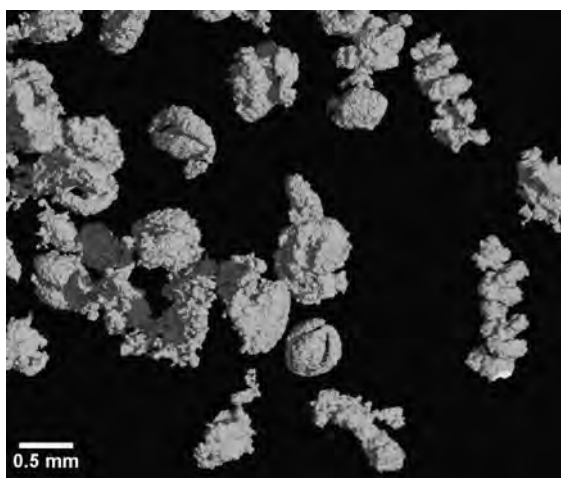


Figure 7. Detail of the rendered biogenic pore structure of the Noyant Fine limestone

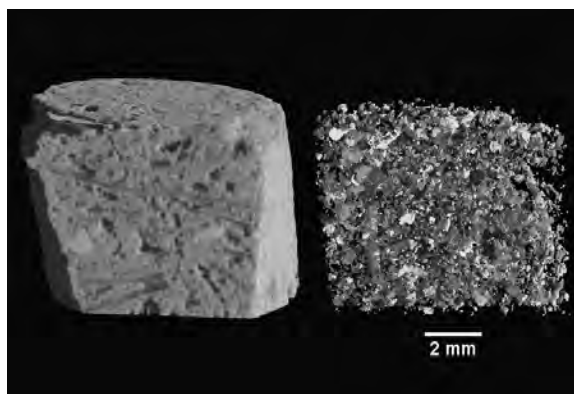


Figure 8. 3D rendered volume of limestone on the left side; visualization of the pores on the right side

The nautilus shell has revealed its internal structure, as seen in figure 6.b, d. The different chambers can be distinguished and they form a nearly equiangular spiral. All septa are pierced in the middle by a duct, the siphuncle. The rendered volumes are made in VGStudioMax. The software program makes this possible to cut through the object in all directions. Additional tools such as re-colouring, segmentation, different light sources and stereo properties can be unlocked to embellish the visualisation.

## 5. CONCLUSION

This study opens the possibility for a whole range of studies concerning Cultural Heritage. A flexible X-ray CT system, using a compact X-ray source, proved to be useful to investigate the internal structure of bronze museum objects, biological samples and natural building stone, in a non-destructive way.

Repairing interactions can be revealed, since different repairing products have a different X-ray attenuation. This enables the visualization of the different materials used. A draw-back is the fact that no real element identification can be performed in 3D, only an indication of a difference in density or atomic number. It also has been shown that, although the current set-up allows us to investigate bronze objects to a certain extent, an optimization could be possible. By using a detector more sensitive to higher energies and/or an X-ray tube with a higher voltage, the artefacts due to beam hardening and insufficient penetration of the sample, could be significantly reduced.

Topics like porosity inside stone samples can be investigated. Changes of the pore structure during weathering processes can be visualised and quantified with the assistance of Morpho+. New restoration materials for buildings of historical interest can thus be visualised, sorted and recorded. Porosity, internal structure of the pores and mineral distribution can be compared with the original material to assist the restoration in welfare to our historical buildings.

3D databases of the rendered volumes of valuable museum artefacts, biological samples and fragile objects can provide an informative and educative advantage. Objects can reveal their internal structure without being cut. 3D X-ray CT images and movies can be obtained for virtual museums and galleries. At the museum, visitors can now virtually cut and look through the digitalized object, projected on a screen, while they are standing next to the original object.

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# **ICT in CH Museums**



## CROSS-MEDIA AND UBIQUITOUS LEARNING APPLICATIONS ON TOP OF ICONOGRAPHIC DIGITAL LIBRARY

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**KEY WORDS:** Digital Libraries, Ubiquitous Learning, Iconography

### ABSTRACT:

Today there are a large number of digital archives, libraries and museums with rich digital collections representing the European cultural and historical heritage. The new challenge shifts from having access to resources to making an effective use of them and avoiding information overload. A possible answer to this challenge is the approach, promoted by the LOGOS project *Knowledge-on-demand for Ubiquitous Learning*. In the frames of this project a learning platform has been developed in which the objects from large-scale repositories of digitized texts, graphics, audio and video materials are being transformed into learning content, taking into account possibilities for cross-media delivery among others. This has proved to be of a great importance when dealing with distributed artifacts. The present paper describes the process of transformation of the digital objects into learning content for the development of various coursewares. For this purpose the authors are using a specific learning scenario, viz. *Access-on-Demand for Studying East-Christian Culture and Art* developed on the basis of the LOGOS Authoring studio and the content of its knowledge repository *Virtual Encyclopedia of Bulgarian Iconography*.

### 1. INTRODUCTION

In an attempt to answer the need for presentation and preservation of the Bulgarian iconography, a team from the Institute of Mathematics and Informatics has developed a multimedia digital library called *Virtual Encyclopedia of Bulgarian Iconography* (<http://mdl.cc.bas.bg>). It was designed so as to provide wide accessibility and popularization of the works of the Bulgarian iconographers, and moreover to enable future precise restoration of the icons at risk.

The team having developed this digital library was involved in the European project LOGOS *Knowledge-on-Demand for Ubiquitous Learning*. The main objective of the project – to contribute to the adequate enhancing and facilitating the knowledge building during eLearning processes, presupposed the existence of large-scale repositories of digitized information and tools for their transformation into learning content. This made it natural to use the already developed *Virtual Encyclopedia of Bulgarian Iconography* as one of the knowledge repositories of the LOGOS platform. The present paper deals with the process of development of courseware on the basis of the information from the *Virtual Encyclopedia* starting with a short description of the digital library itself, than explaining the process of its transformation into LOGOS ontology and at the end – tracing the steps for the development of courseware objects.

### 2. THE VIRTUAL ENCYCLOPEDIA OF BULGARIAN ICONOGRAPHY

Up till now the digital library *Virtual Encyclopedia of Bulgarian Iconography* includes approximately one thousand digitized images of Bulgarian iconography by various artists, historical periods and schools. The digital objects are grouped into thematic collections according to their topics. For each object special detailed descriptions are created. They include

data about the title, the artist, the period of creation of the work, the school, the dimensions, the technique, the base material, the category, the location, the author (biographic data), comments, etc. An important part of the digital library is the one with the descriptions of iconographic techniques and significant iconographic schools – works and biographies of well-known Bulgarian iconographic artists. A glossary of important terms is also included. The works presented in the library originate from the twelfth to the beginning of twentieth centuries. Amongst them specimens from the following schools and regions of Bulgaria are included: Bansko-Razlog iconographic school, Triavna iconographic school, Samokov iconographic school, icons from Veliko Turnovo, Sozopol, Rila Monastery, Arbanassi, etc.

This digital library contains diverse hypertext-organized collections of information (digital objects such as text, images, and media objects) to be used by many different users. Its main characteristics (e.g. ability to share information, new forms and formats for information presentation, easy information update, accessibility from anywhere, at any time, services available for searching, selecting, grouping and presenting digital information, extracted from a number of locations) are of a great importance for the access-on-demand learning. Using these services depends on the user's preferences, needs and wishes, i.e. there is personalization available, contemporary methods and tools for digital information protection and preservation, ability to use different types of computer equipment and software, etc. (Pavlov and Paneva, 2005).

In the past digital libraries were isolated and monolithic systems limited to access to content of a single provider. The development of the technologies during the last years provides new functionalities and advanced services to contemporary digital libraries such as specialized services for multi-layer and personalized search, context-based search, relevance feedback, resource and collection management, metadata management, learning content personalization and context awareness, content

indexation, semantic annotation of digital resources and collection, etc.

In order that digital libraries could be used efficiently as a source of knowledge in the eLearning specific features and principles are to be formulated. Here follow some examples.

- Digital libraries are expected to provide knowledge resources to the end user on-demand.
- Furthermore, they should provide tools and technologies in support of indexing, cataloguing, retrieving, aggregating, and creatively exploiting different textual, non-textual and complex objects and resources.
- In addition, the new eLearning trends require the implementation of tools for personalized preference-based access to digital libraries. Thus the data presented to the user would be reduced significantly as a result of filtering, extracting and aggregating digital objects in accordance with his/her preferences
- The objects in the digital libraries should be segmented, annotated and semantically indexed so that metadata attached to them could include semantic descriptions based on appropriate domain ontologies.
- The metadata should be written by means of standard description languages and stored in an appropriate metadata repository. The management services should enable a content-search on various parameters including efficient retrieval based on Boolean and similarity queries. It is important that any approach would facilitate the retrieval rather than force the user to search across the entire resource.
- Moreover, digital libraries should establish protocols, standards and formats most appropriate for the use and the assembly of distributed digital libraries and their resources (cf. Pavlov and Paneva, 2006).

### 3. THE ONTOLOGY OF BULGARIAN ICONOGRAPHICAL OBJECTS

As already mentioned, the digital library *Virtual Encyclopedia of Bulgarian Iconography* had to be transformed into domain ontology so as to be used as a learning content inside the LOGOS Authoring Studio. This ontology was named *Bulgarian Iconographical Objects*. In the hierarchy of data models of LOGOS architecture the digital objects are media objects accompanied by identification, technical and semantic metadata. Learning objects are (combinations of) digital objects, complemented by educational metadata (Marinchev et al., 2007). Courseware objects integrate learning objects according to schemes of learning experiences (Arapi et al., 2007). Authors of learning materials have access to digital archives. They search for appropriate digital objects, and combine them in learning objects and further – in courseware objects using the services of the LOGOS Authoring Studio. The aim of offering an easy access to digital archives determines the requirements to the *Bulgarian Iconographical Objects* ontology and its development process.

The *Bulgarian Iconographical Objects* ontology was implemented by means of the Ontology Management Tool of the LOGOS Authoring Studio called CoGui (see: <http://gforge.lirmm.fr/projects/cogui>) and was developed in the Montpellier Laboratory of Computer Science, Robotics, and Microelectronics. CoGui provides functionality to create and maintain multilingual vocabularies of concept types and relation

types and also functionality for posing constraints, rules, fact graphs, prototypical graphs, pattern graphs, etc.

During the creation of the *Bulgarian Iconographical Objects* ontology the concepts and properties of CIDOC ontology were observed. Parts of them were used in our ontology, other parts were transformed in order to fit for the iconography domain, and several concepts did not belong to the CIDOC Conceptual Reference Model ontology.

The chosen digital library architecture is a hypermedia digital library. The resources are digital objects of different formats – text, graphics, and other media. They are structured in a hypermedia manner, i.e., some digital objects point to other ones. In this way the user can navigate quickly, in a non-linear fashion, within areas of related topics, using the hyperlinks. In this stage the *Search* service aids the visitors in finding a certain object by the following criteria: icon title, author, period, type, school, region and location. The search can be conducted by one or by more criteria. Our current development provides personalized and context-based search (Paneva et al., 2005, Pavlov et al., 2005, Pavlova-Draganova et al., 2006).

The LOGOS project addresses innovative development of the main components of the learning processes – resources, services, communication spaces. It aims at achieving new functionality of the learning communication spaces by integrated web, digital television and mobile technologies, supporting cross-media learning content. New eLearning management systems based on this integration are orientated towards an improvement and an extension of the learning services within new consistent pedagogical scenarios. The use of annotated and adequately structured knowledge from digital archives enables lecturers/authors to participate in *open source* content development from massive, dynamically growing learning resources (LOGOS).

### 4. ACCESS-ON-DEMAND FOR STUDYING EAST-CHRISTIAN CULTURE AND ART

The various project teams, from eight partner countries, generated future usage scenarios related to different user groups, contexts and topics. Scenarios are used in systems design to describe typical or important uses of the system as narratives or stories. They are designed to give designers, developers, users and managers a shared understanding of the purpose of the system and the ways it will be of use in practice (Pemberton et al., 2007).

The scenario we are going to present here is *Access-on-demand for studying East-Christian culture and art*, developed by the team of IMI. It is created according to several learning situations and communication channels. It involved a wide range of users both attached and unattached to formal educational programs. The scenario has several variants and for each of them the following characteristics are specified: learning background (topic area), learning situation, link to curriculum, learning setting i.e. support, place, time, devices used, learner background (age range, role and occupation, motivation type, etc.), planned learning activities, types of material accessed, specific objectives, learning approach, interactive functions needed/used by learner glossary, etc. (Pavlov and Paneva, 2006).

## 5. LOGOS AUTHORIZING PROCESS

From a user's point of view, one could imagine various authoring scenarios for courseware development for Learners using content residing at external archives. The simplest and straightforward scenario presented here is the bottom-up scenario, starting with the creation of *media objects*. This overall scenario is depicted in Figure 1.

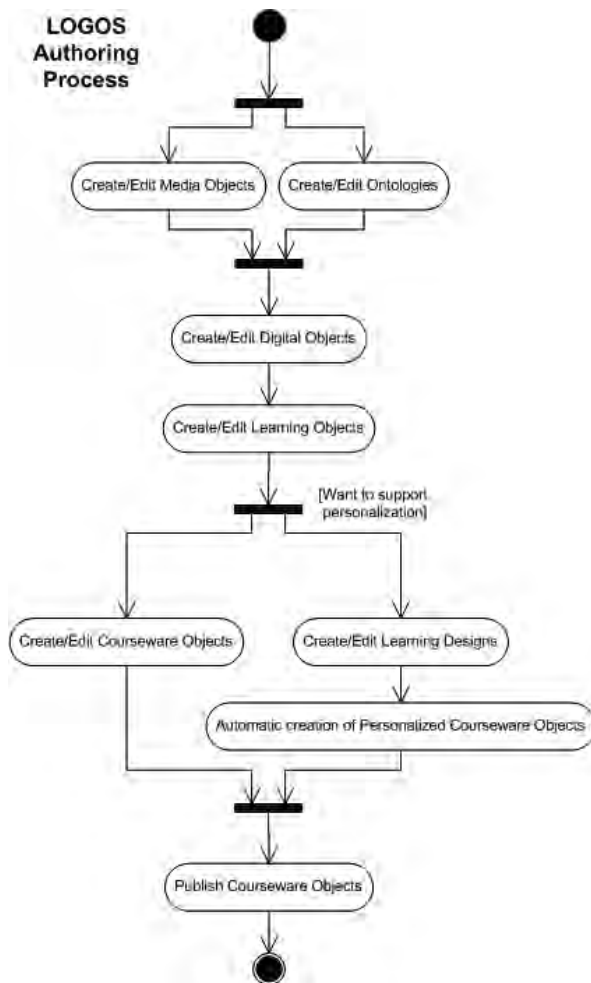


Figure 1: The overall authoring process in LOGOS

The editing process starts with building *media objects* and *ontologies* which form the basis of *digital objects* to be used further to create higher level objects (e.g. *learning objects* and *courseware objects*). Creating *media objects* and *ontologies* can take place in parallel.

The next step in the LOGOS authoring process is the creation of *digital objects*. This activity essentially consist in attaching appropriate metadata to the available *media objects* (or to parts of them) in order to include semantic annotations based on the available *ontologies*.

One can further create *learning objects* as collections of related *digital objects* that can be used to accomplish a specific learning objective. Such collections are further enriched by the *learning object metadata* (LOM).

The usage of *learning objects* in order to create *courseware objects* represents the next step in the process. It can be done in two approaches:

- One can statically create *courseware objects* by defining hierarchies of *learning objects* and by specifying their sequencing and presentation characteristics. (This is the most straightforward option.)
- If one wants to support personalization appropriate *learning designs* should be defined first. These are abstract training scenarios capturing the pedagogical characteristics of a training process for a certain subject without direct reference to the *learning objects* available for implementation of this training process.

The binding of training activities with the *learning objects* is done by an automatic mechanism enabling the creation of personalized *courseware objects* based on information about the user characteristics (this information can be extracted from a *learner profile*). The output of this automatic process represents *courseware objects* similar to the ones created manually in the case of static *courseware creation*.

The final activity in the authoring process is the publishing of *courseware objects* ready to be used by the *learners* by means of different devices (PCs, mobile devices, digital TV). Publishing a *courseware object* essentially means to decide on how the content will be presented to the end-user and what devices will be supported (Pavlova-Draganova et al., 2007).

Let us illustrate the static approach for the development of a courseware object entitled *Leading Bulgarian iconographic schools – style and achievements of the Bansko-Razlog iconographic school*. We used the *Courseware objects editor* to create the courseware objects by defining a hierarchy of the following *learning objects* (LO):

- LO1: Introduction to Bansko-Razlog iconographic school;
- LO2: Famous iconographic characters painted by iconographers from Bansko-Razlog iconographic school;
- LO3: Famous iconographic scenes painted by iconographers from Bansko-Razlog iconographic school;
- LO4: Saint Nicholas painted by iconographers from Bansko-Razlog iconographic school and other famous iconographic schools;
- LO5: *The Nativity of Christ* scene painted by iconographers from Bansko-Razlog iconographic school and other famous iconographic schools.

As it can be seen the *learning objects* follow the natural steps of the learning process: introduction to the iconographic school as a whole; presentation of the images of characters famous for this iconographic school, presentation of iconographical scenes representative of this iconographic school, and orientation between the various styles of representation of one and the same scene or character in the different iconographic schools.

All the *learning objects* are being managed in the *learning objects repository*. They are built on top of digital objects and enriched by *learning metadata*.

To develop the *learning objects* of *Leading Bulgarian iconographic schools – style and achievements of the Bansko-Razlog iconographic school* courseware object we used the *Description tool for learning objects*. By means of this tool we created *learning metadata* for digital objects and combinations



of such objects. For this purpose we used some *digital objects* (DO), viz.

- LO1:
  - DO1 – School description (shows several specimens created by famous iconographers from the Bansko-Razlog iconographic school);
  - DO2 – Representative specimens' demonstration
- LO2:
  - DO1 – *The Holy Mother of God* (The Virgin Hodegetria) character by D. Molerov, Bansko-Razlog iconographic school;
  - DO2 – *The Blessing Christ* character by unknown iconographer, Bansko-Razlog iconographic school;
  - DO3 – *Saint John the Forerunner* character by unknown iconographer, Bansko-Razlog iconographic school (Figure 1);
  - DO4 – *Saint Archangel Michael* character by I. Terziev, Bansko-Razlog iconographic school;
  - DO5 – *Saint George* character by unknown iconographer, Bansko-Razlog iconographic school;
  - DO6 – *Saint Dimiter* character by D. Sirleshtov, K. Marunchev, Bansko-Razlog iconographic school.



Figure 1: *Saint John the Forerunner* character by unknown iconographer, Bansko-Razlog iconographic school

- LO3:
  - DO1 – *The Holy Forty Martyrs* scene by unknown iconographer, Bansko-Razlog iconographic school;
  - DO2 – *The Ascension of the Prophet Elias* scene by unknown iconographer, Bansko-Razlog iconographic school;
  - DO3 – *The Elevation of the Venerable Cross* scene by D. Sirleshtov, K. Marunchev, Bansko-Razlog iconographic school;
  - DO4 – *The Ascension into Heaven of Christ* scene by D. Molerov, Bansko-Razlog iconographic school.
- LO4:
  - DO1 – *Saint Nicholas* character by D. Molerov, Bansko-Razlog iconographic school (Figure 2);

- DO2 – *Saint Nicholas* character by Ch. Dimitrov, Samokov iconographic school;
- DO3 – *Saint Nicholas* by D.Zograph from Sozopol, Strandja iconographic school;
- DO4 – *Saint Nicholas* by S. Tsanyov, Tryavna iconographic school
- LO5:
  - DO1 – *The Nativity of Christ* scene by T. Vishanov, Bansko-Razlog iconographic school (Figure 3);
  - DO2 – *The Nativity of Christ* scene by unknown iconographer, Strandja iconographic school;
  - DO3 – *The Nativity of Christ* scene by unknown iconographer, Tryavna iconographic school.



Figure 3: *The Nativity of Christ* by T. Vishanov, Bansko-Razlog iconographic school

All the *digital objects* are managed in the *Digital objects repository*. They are created on top of *media objects* or parts of them, annotated and indexed with administrative and semantic metadata. As far as the *media objects* are concerned, they are being managed in the *Media server*. They are coming from external content archives – in our case the *Virtual Encyclopedia of Bulgarian Iconography*.

We have presented in a nut shell the experience of our team in transforming a digital library into a knowledge repository. During our joint work in the context of the LOGOS project we gained a deeper understanding of the new opportunities the digital libraries offer as a learning resource.

An experimental testing of such scenarios is currently being carried out among university lecturers and students and the analysis of the results will be available in the nearest future.

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## A MOBILE EXPLORER FOR THE HISTORICAL CITY OF SALZBURG

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**KEY WORDS:** Mobile city guide, cultural heritage, interactive, localization services

### ABSTRACT:

This project paper presents the “Wanderbarer Salzburgführer”, an innovative mobile application for the City of Salzburg, with a focus on mediating cultural and historical information in an experiential learning environment. We describe the concept of the mobile application, its main features, the technology behind it and look at the findings of the August 2007 user trial in Salzburg. Our main research interest was to a) investigate how users can be encouraged to experience the (physical) authentic cultural heritage with the aid of rich multimedia content delivered via location-aware mobile technology and b) learn how this impacts the way in which users navigate through the physical environment. The application was developed with the residents of Salzburg in mind and focused on the lesser-known cultural heritage of Salzburg. The digital narratives followed a moderate constructivist approach in encouraging users to actively engage with the city’s cultural heritage. Utilizing mobile technologies and a multi-level content management system, a navigational model was developed that automatically linked all content and made it possible for users to create their own trails through the city. A story engine editor was also developed to enable non-technical professionals to edit storylines and integrate interactive features. The 2007 trial reinforced our initial assumptions that users, when given the option, tend to create their own exploration paths through a city rather than follow pre-selected thematic trails and that interactive rich media is a valuable asset in stimulating users to actively engage with a city’s cultural and historical heritage.

## 1. INTRODUCTION

### 1.1 Motivation

This project paper presents the “Wanderbarer Salzburgführer”, a mobile city explorer that was developed, implemented and tested within the INTERREG IIIB CADSES project Heritage Alive! ([www.heritagealive.eu](http://www.heritagealive.eu)) (2006-2008). The project comprised a network of nine partners from seven Central and Eastern European countries. Its main aim was to identify, develop and implement applications utilizing new media and technologies for communicating and mediating cultural heritage content to both visitors and residents. Part of the project was to develop and test a prototype for a mobile explorer for the Historical City of Salzburg.

The main idea of this city explorer was to create a mobile application that would allow the residents of the city and the state of Salzburg to actively explore and experience the authentic (physical) cultural heritage of Salzburg. Initial intentions for developing a mobile tour guide for tourists were discarded as, on the one hand, Salzburg is already a popular and well-developed tourist destination while, on the other hand, residents often know very little about the history and cultural heritage of their city.

### 1.2 Aims

Against this background, we decided to build a mobile application that would allow the residents of Salzburg to explore some of the city’s cultural heritage sites and, indirectly, also raise their awareness of the value of this heritage and the necessity to preserve it for future generations. Our main research interest in this respect was to a) investigate how users

can be encouraged to experience the (physical) authentic cultural heritage with the aid of rich multimedia content delivered via location-aware mobile technology and b) learn how this impacts the way in which users navigate through the physical environment.

### 1.3 Structure of the Project Paper

First the concept of the Salzburg mobile city explorer and the narrative approach applied is described (chapter 2). Chapter 3 outlines the technology and user interface of the mobile city explorer and chapter 4 depicts the experiences and lessons learned in developing and implementing it. Chapter 5 presents the main findings of the user trial in Salzburg in August 2007 and chapter 6, finally, summarizes the project paper.

### 1.4 Overview and References to Related Work

This section takes a look at secondary research on the theme of web-based mobile information and storytelling applications. As the vision of delivering digital content and services anywhere, anytime to any device becomes a technical reality the commercial interest in the underlying technologies has heightened. This is especially true of the tourism domain as evidenced by the current boom in mobile tourist guide services around the globe. So as an early adopter the tourism domain offers an ideal starting point to examine the latest developments in web-based mobile information and storytelling solutions. By merging mobile technology with dynamic content management systems it is now possible to offer the user a greater level of personalized tourism services. In the paper “Context-awareness in Mobile Tourism Guides” (Schwinger, Grün, Pröll, Retschnitzegger and Schauerhuber, 2008) the strengths and weaknesses of a number of web-based mobile tourism guide

applications in delivering context-aware services are presented. A total of seven mobile tourism guides were investigated according to an original evaluation framework, which focused on context and adaptation criteria. The technical critique included such issues as not applying industry standards in the use of positioning technologies or developing content management systems that are extensible or the long debate about thin and thick clients. A recommendation of particular interest to our project is the fact that systems should not lock users in or lock others or content out. It was pointed out that "*Tourism is a social activity*", so the next generation of mobile tourism applications need to leverage the creation and sharing of user-generated content and not inhibit it.

In the paper "Adaptation of Storytelling to Mobile Information Service" (Kim and Schliesser, 2007) the focus was on changing the "*nature of cultural and historical tourist experiences in ubiquitous city environments*". The approach was to engage the user by providing task-based activities in an enjoyable environment. "*The intended effect of combining a site-specific walking tour with an entertaining fictional historical story and offline quest game was to make mobile users more interested and involved in the area they were touring*". By the use of story/game elements the user was provided with the objective to finish the tour. The use of game-like presentation techniques to motivate users to experience cultural and historical information supports our overall concept in the Salzburg Mobile City Explorer. In fact our concept developed towards providing users maximum freedom in creating their own tours through the city environment, allowing them to be guided or not by context triggered stimuli (see below).

Related work also includes the paper "Narratives for Exploring Digital Content in Physical Spaces", which was presented by the authors at the IEEE SMC International Conference on Distributed Human-Machine Systems in Athens, Greece, in March 2008. The paper focused on the narrative approaches applied by the "Wanderbarer Salzburgführer" and analyzed how novel narrative approaches delivered to mobile end devices can enhance a user's experience in exploring a city's cultural heritage.

## 2. THE SALZBURG MOBILE EXPLORER

### 2.1 The Concept of the Salzburg Mobile Explorer

The Salzburg mobile explorer focuses on the city's less well-known historical and cultural heritage attractions: More than 50 points of interest from six different themes are presented in the prototype of the "Wanderbarer Salzburgführer" (the "walkable Salzburg guide"):

- Georg Trakl: The Life and Works of a Salzburg Poet,
- Latin Inscriptions: What Inscriptions Tell Us,
- Historical Taverns, Breweries and Hotels,
- Salzburg through the Ages
- Historical Doors, and
- Historical Windows.



Figure 1: The start page of the mobile city explorer; the six images represent the entry points to the six themes @ Salzburg Research 2008

The points of interest are set at historical buildings, monuments or places in the historical city - and cover various aspects of the respective themes through short stories. The stories feature a mixture of facts and anecdotes and utilize different media, including text and images as well as audio and video material. To actively engage users in the stories and the physical heritage of the city, the mobile explorer offers a series of interactive features, including riddles and quizzes, tasks or scavenger hunts. To explore the city users can either follow one of the six thematic trails or create their own path through the city by using the system's dynamic navigation system. In this way users can select those points of interest they are most interested in or establish links between the various points of interest, i.e. they can visit geographically nearby or thematically and historically related points of interest. Or, users can explore the city by chance—i.e. they can simply walk through the city and a small indicator points out any point of interest they pass.

### 2.2 Narrative Approach

We adopted a moderate constructivist approach (Karagiorgi and Symeou, 2005; Mayer, 1999; Peterson and Levene, 2003) for mediating the historical and cultural heritage information of the city to residents. According to this view, knowledge is not transmitted but can only be actively created by users through personal experiences. To stimulate these personal experiences users should be

- encouraged to active "learning",
- assisted in authentic "learning", and
- provided with multiple perspectives on "learning".

To promote *active learning* the Salzburg mobile explorer enables users to engage in various task-based, problem-solving and game-like activities, such as small exercises, questions, riddles, quizzes or scavenger hunts. Moreover, users have the opportunity to create content and share it with others (for example, users can comment on Georg Trakl poems and share their impressions with other users).

To enhance *authentic learning* the stories of the different points of interest are anchored in the real-life environment. For example, to introduce visitors to the ongoing debate about the design of Makartplatz (i.e. if it should be a green space or a traffic space), users are invited to watch a narrated video at a specific spot in the Makartplatz from where they can experience "live" both the heavy traffic as well as the beauty of the small park in the centre of the square. Or actual (physical) tablets

with Georg Trakl poems in the city serve as entry points into different aspects of Georg Trakl's life and works. Digital content (provided on the mobile devices) is presented in such a way that users are stimulated to actively engage with their physical environment. For example, users (provided with an image of the door or window, as well as their approximate location) have to find a specific historical window or door in the city or guess the meaning of selected Latin inscriptions.

Finally, to provide users with *multiple approaches to learning*, the presentation of and interactive approaches for the six themes and individual points of interest were varied as much as possible. For example, the Historical Taverns, Breweries and Hotels theme is depicted in the form of short anecdotes, accompanied with historical images while the Salzburg through the Ages theme is covered in the form of narrated videos and an interactive quiz. The Historical Windows and Historical Doors themes are an exception with the same (scavenger hunt) approach applied.

### 3. TECHNOLOGY

#### 3.1 Application Architecture

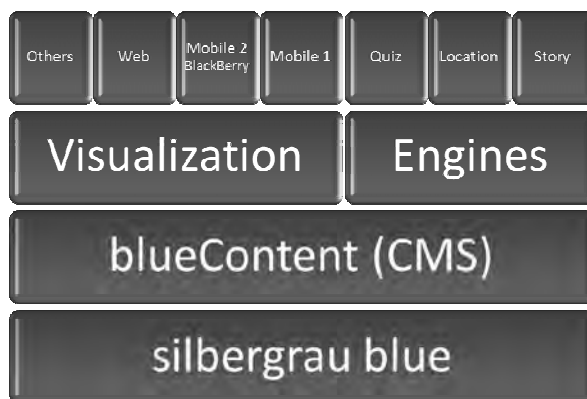


Figure 2: Architecture of the mobile explorer @ Silbergrau Consulting & Software GmbH

Figure 2 shows the architecture of the mobile city explorer: The mobile city explorer is a JEE (Java Platform, Enterprise Edition) application built on an Enterprise framework ("silbergrau blue"). On top of this base system is an Enterprise Content Management System (ECMS, "blueContent"). While these base components may seem "unusual" for mobile city guides, they provide key features for the "Wanderbarer Salzburgführer":

- 24x7: The "Wanderbarer Salzburgführer" is an application designed for 24x7 operation, i.e. visitors can explore the city at any time (or browse through the web pages);
- High availability and scalability: As the application has to be accessible 24 hours a day, constant availability is a key aspect. Also, as the system is designed to support thousands of users and (live) visitors, the system has to be scalable out of the box;
- The Content Management System provides full media integration, authoring workflows, integrated security, scaling and conversion of images, template handling and semi-automatic linking of content;

- Multiple user interfaces may be "plugged in". The mobile city explorer currently supports three interfaces: two for different mobile devices (Blackberry and Ultra Mobile PCs) and a Web interface;
- Application development made easy: Features such as object-relational mapping, in-memory-transactions or Java Management Extensions (JMX) are provided out of the box;
- An integrated knowledge management component provides the ability to analyze different types of content and to correlate them.

These base systems are customized and extended by so-called "engines". These engines provide new functionalities via a plug-in mechanism: multi-relation narration, localization and integration of quizzes (see below for details). The frontend is completely separated from the base system and the application. It consists of a template engine with various templates and a dynamic caching system. The template engine renders the user interface contents and maintains image conversion, server-side scaling and front-side indexing. The dynamic caching engine caches content of any type for system performance and fast delivery. Content updates are handled with respect of their relations to other content. Thus, cache updates are performed for very small, isolated sets of content. In addition, the dynamic caching engine manages and seamlessly integrates dynamic (= program created) content.

#### 3.2 Location and Quiz Engines

The various engines are plugged into the mobile city explorer and provide a base for the easy extension of the system. The most important engines are the Location Engine and the Quiz Engine. Considerable effort was invested to ensure a robust and accurate localization service (e.g. GPS or GSM based solutions), able to work in the narrow streets and alleys of the Historical City of Salzburg. In the end, a GPS based solution was adopted (Figure 3 shows the component diagram of the Location Engine).

The user interface provides for the easy handling of location-based information (such as points of interest) within the backend as well as the frontend. A map integrator stack provides independence of location based service providers, such as Google Maps (see <http://maps.google.com>, <http://maps.google.at>) (which we used for the tests) or Virtual Earth (<http://www.microsoft.com/VirtualEarth>).

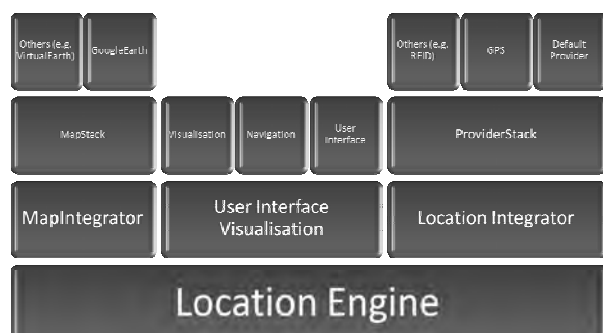


Figure 3: Component diagram of the Location Engine @ Silbergrau Consulting & Software GmbH

While the architecture of the Quiz Engine is not as complex as the Location Engine, the implementation was very time-consuming. This is due to the fact that we had to build a *generic* Quiz Engine which supports the integration of various types of quizzes and feedback, such as single/multiple choice questions, text fragments or multi-level and modal feedback. The Quiz Engine is based on the IMS Question and Test Interoperability-Standard<sup>4</sup>, version 2.1 Public Draft (revision 2) (see <http://www.imsglobal.org>). To support the easy generation of quizzes, an integrated quiz editor was provided within the WYSIWYG (What-You-See-Is-What-You-Get) editor of the ECMS.

### 3.3 Multi-relation Narrative Engine

The core of the mobile city explorer is the underlying concept for user navigation, maintained by the so-called “Multi-Relation Narrative Engine”. This engine provides the basis for a multi-relational navigation through the contents of the mobile explorer (and the physical city), with the system “assisting” the users by automatically pointing them to any related content, such as (real world-based) nearby and historically or thematically related content.



Figure 4: (1-4) main menu, (5-11) navigation between contents, (6-9) multi-relation navigation, (10) nearby PoI indicator @ Salzburg Research 2008

While such a multi-relation navigation system may also be created manually (by creating all relations for all content manually) this would be an extremely time and resource intensive approach and not practical for a system that is intended to be extended by both editor and end-user created content (including new themes and points of interest). With the Salzburg mobile city explorer we followed a different approach: the system itself supports the user and automates the creation and maintenance of (possible) relations between content:

- *Location-based relations* (nearby points of interest) are provided through the system by “locating” contents. This locating itself may be done manually (by entering coordinates) or by point and click (via the integration of location services such as Google Maps).
- *Historically related content* is retrieved automatically by examining the corresponding category (epoch) information.
- *Content relations are created* and maintained automatically through the Knowledge Management Engine of the underlying ECMS by analyzing and relating all content (e.g. articles, quizzes, pictures or movies) and putting them in relation.
- A *WYSIWYG editor* within the ECMS backend allows non-technical personnel to easily create content and storylines.

At runtime, the system analyzes the user’s current context and searches for related content. The context is defined as a combination of the user’s (real world) position, the current (logical) position within the chosen story (if applicable) and the current content of the visited point of interest. Related content shown by the system may be (geographically) located nearby, set in the same era (historically related) or thematically related to the current content or point of interest. These relations are automatically traversed by the system.

### 3.4 Advantages of the Architecture

This architecture provides several key advantages:

- **High scalability and availability:** A real-world city guide has to be available at all times (24x7) and potentially support several thousands of users at any one time;
- The server based architecture allows for easy system updates and client handling (e.g. system installation or software robustness) and the server based processing allows for operations which would not be possible on a rather low-performance device such as a UMPC or a mobile device such as the Blackberry (e.g. automatic image scaling or playing large videos);
- The architecture enables a real “live” (i.e. new user or editor created content becomes immediately visible to users) and interactive system (with quizzes to solve and tasks to complete). This is relatively easy to achieve in a server based environment (as the server “knows” everything about its users: e.g. their position, content they accessed or content they have created) whereas it is rather complex to realize in a distributed environment;
- **Flexibility:** The concept of using pluggable engines proved to be extremely valuable as several key aspects (e.g. quiz support) had to be changed during the development of the mobile city explorer. These changes, however, did not affect other parts of the system even though it affected both the content editor as well as the client user interfaces.

### 3.5 Interface and Navigation

The application architecture (see figure 2) strictly separates the user interface from the application/content layer. This made it possible to support three user interfaces—one interface for web browsers and two for mobile clients.

The web interface was developed to attract the attention of potential users. While most of the mobile explorer’s content can be accessed on the web, several key features (e.g. the videos and audio files, some quizzes or the scavenger hunts) or local-specific services can only be accessed by using the mobile clients. Another reason for developing a web client was to support the content generation and iterative testing of the application throughout the development process.

Furthermore, interfaces for two very different mobile clients were developed: one based on a UMPC (Medion MD RIM 1000), the other one based on a Blackberry (series 8800 and 8310). The reason for developing two mobile interfaces is that they offer very different functionalities that we deemed relevant for realizing the concept of our mobile city explorer (see chapter 2): the UMPCs with its relatively large screen and high screen resolution and keyboard in contrast to the more versatile

and durable mobile device with a long battery lifetime, integrated GPS device and better readability in direct sunlight. However, as the interface for the Blackberry was developed in early 2008, only the UMPC interface could be tested in the trial in August 2007 (see section 4.4 and chapter 5).

Although the clients are technically very different from each other, the mobile city explorer uses the same base technology for all three devices: on the client side the user interface uses XHTML and JavaScript for the dynamic elements; the rendering and processing of content as well as the navigation is server based. For the interface of the mobile devices a small (Java ME) program is used to provide the server with the geographic position of users.

The interface (for both the mobile and the web applications) consists of the following elements:

- the main page,
- thematic overview pages (for each of the six themes),
- an overview as well as a directions page for each points of interest, and
- the content pages.

The main page allows users to access the six themes. Each theme is represented by an image. By clicking on an image users may access the specific theme. Having selected a theme, users are taken to the theme overview page which introduces the theme and features a map with all the theme's points of interest. The Salzburg city explorer uses Google Maps, but in fact any location service provider (such as Virtual Earth) may be used. By clicking on one of the points of interest (indicated by yellow balloons), a pop-window offering a preview (i.e. the title of the point of interest and a short teaser to raise the users interest) of the selected point of interest opens. Users are then taken to an overview page that provides a short introduction and an image of the point of interest. If they are interested in visiting the point of interest, they are provided with the directions. These are presented through an enlargeable navigation map (again, the mobile city explorer uses Google Maps, see above) indicating the locations of both the point of interest and the current user position. This information is combined with additional text-based directions to provide orientation along well-known places, buildings or streets.



Figure 5: Selecting a point of interest on the Google Map of the theme overview page @ Salzburg Research 2008

Using the “forward” and “backward” buttons, users can navigate through the various content pages. The last content page indicates how users can continue their journey through the city (i.e. using either the home page to select another theme or the above mentioned dynamic navigation elements).

## 4. LESSONS LEARNED: BUILDING THE SALZBURG MOBILE EXPLORER

### 4.1 Concept Development

The concept for a mobile explorer for the Historical City of Salzburg was developed in collaboration with the Referat für Altstadterhaltung (Department for the Preservation of the Historical City of Salzburg) of the State Government of Salzburg (Land Salzburg). In this phase we identified the main target group (i.e. the residents of Salzburg) and the themes and content to be presented on the mobile city explorer. We then developed story scenarios, including potential interactive features to stimulate user interaction. Finally, after having identified the mobile devices and localization technology, we specified the interface and user navigation details.

### 4.2 Technical Development and Deployment

Technical development encompassed the following processes:

- Adaptation of the mobile devices;
- Adaptation of the content management system towards the functional requirements of the mobile explorer (e.g. to include interactive features);
- Development of the Multi-relation Narrative, Quiz and Location Engines;
- Interface design and development;
- Provision of localization services;
- Overall technical integration, including the pre-testing of the mobile city explorer.

For our mobile explorer we built on existing technologies to meet the needs of the project. This allowed us to focus on the aspect of mediating cultural heritage content rather than advanced technical development. Most of the development process was iterative, with the results from the testing phase feeding back into the development and refining of the mobile explorer. Experiences in the technical development phase were mostly positive, although we encountered a few technical problems, which had to be overcome.

Hardware in particular was a problem. Since the main focus of the Salzburg mobile explorer was on presenting and mediating multimedia and interactive cultural heritage content, we decided to acquire Medion ultra mobile PCs (UMPC) as these had (in 2006) several advantages in comparison to mobile phones and PDAs: a relatively large screen to present information in a well-readable form; support for server and browser based applications; an integrated keyboard; and the playing of high quality audio and video files. Since UMPCs then were a relatively new technology, however, they were not delivered until May 2007, which delayed the overall development and implementation process considerably. Integrating the localization services was another obstacle in the technical development process. An initially favored solution to utilize GSM interpolation technology did not prove feasible as local telecom providers either did not provide this service, or the service was insufficient in accurately localizing the user position. The solution finally chosen, GPS localization, proved to be quite effective and easy to implement, although the GPS performance was at times poor, with the loss of signal in the very narrow streets or alleyways of the city being a particular challenge.

### 4.3 Content Collection and Provision

Content collection and provision included the following activities:

- Agreeing on general content concepts for presenting the themes;
- Collecting of relevant content (e.g. from archives, museums and other cultural heritage institutions) and selecting what will be included;
- Initial writing phase;
- Selection of relevant illustrations to support the texts;
- (Iterative) text editing and re-writing;
- Content validation (e.g. by historians or curators);
- Adding of audio and video material; and
- Designing and integrating interactive features (e.g. quizzes).

This process was much more time- and resource intensive than initially anticipated. The iterative writing and rewriting process was particularly laborious, as texts had to be adapted towards the requirements of the end device and mobile use—i.e. texts had to be short and easy to read (in fact, a recurring comment in the user trial was that some of the texts were still too long or academic in style). While initially we thought that it might be difficult to gain the consent of relevant heritage institutions for using material, in particular historical images and audio and video material, the local and regional stakeholders proved, in fact, extremely supportive in offering advice and in pointing to and providing high-quality content. To create the various stories we utilized an online enterprise content management system (ECMS) with a WYSIWYG editor, which enabled our editors (usually persons with little technical background) to create, add and edit content—including the interactive feature—without the help of software engineers.

### 4.4 Salzburg User Trial in August 2007

In August 2007 the mobile explorer on UMPC basis (as noted above, the BlackBerry version did not become available until early 2008) was trialed with 15 test users in Salzburg. The user trial was based on an elaborate evaluation procedure that included a technical as well as user and take-up evaluation. The technical evaluation assessed the technical performance and the stability of the mobile device as well as the quality of the location based services. The user and take-up evaluation assessed the usability of the interface and navigation, the presentation of content as well as the overall tour guide concept.



Figure 6: A test user before a Georg Trakl tablet @ Salzburg Research 2008

In the trial users were asked to test the application according to task-based user scenarios (i.e. they were requested to use the mobile explorer in a realistic scenario). During the trial individual test users were accompanied by qualified personnel to provide, if necessary, help and support, and to document each user trail for later analysis. Following each test, users were also asked to provide further feedback in semi-structured interviews. Finally users were requested to complete questionnaires assessing the quality of the mobile explorer.

## 5. LESSONS LEARNED AND MAIN FINDINGS OF THE SALZBURG USER TRIAL

### 5.1 Stability and Quality of the Technology

In the trial period the system proved moderately stable without major technical problems. Minor technical shortcomings included the complex and time-consuming starting procedure and occasionally imprecise user localization or loss of the GPS signal.

To start the application several programs had to be commenced (often in a particular sequence) before being able to run the actual tour guide: loading the (Windows Vista) operating system, establishing an Internet connection (using GRPS/UMTS), starting the browser, adapting the UMPC screen resolution to the resolution of the application (including changing to full-screen viewing mode), initializing the external GPS localization device and linking it with the application via Bluetooth and, finally, loading the navigation program. The whole starting procedure took several minutes, which was particularly annoying if during a user test the application had to be restarted (e.g. because of the loss of the GPS signal). Thus, for future versions the starting procedure has to be simplified.

User localization was less problematic. Users were usually familiar with the Google Map based navigation interface and had little difficulty in using it. They particularly considered the combination of Google Maps with text-based directions and images showing the surroundings of a selected point of interest as very helpful (the image provided a helpful visual aid), although some users noted that the overall navigation process should be simplified. GPS localization allowed users to concentrate on the content and the city rather than on finding the way. However, while localization worked fine most of the time, the GPS signal was sometimes disrupted or even lost in narrow alleys and passageways. In that case the GPS localization service had to be restarted (a process, which was time-consuming and annoying for users). Depending on the quality of GPS satellite reception, GPS localization also was at times imprecise (with a margin of a few meters).

The server-based solution proved to be one of the major advantages. Server connection was very robust with short loading times of the different contents. And most important, providing the contents through the server created a real “live” system that allowed users to create content and immediately share it with other users.

Using UMPCs as mobile devices had both advantages and disadvantages. The major advantage of the UMPC was the powerful performance (i.e. strong processing power and large memory capacity), the large displays and the ability to run and integrate diverse media and applications. Trial users particularly praised the enhanced readability offered by the



relatively large screen (6.5 inches), including the possibility to viewing videos and images in high quality. Moreover, UMPCs provided a reasonably comfortable keyboard for users to create content (e.g. by commenting on selected Georg Trakl poems and sharing their views with other users), which was a key feature of the mobile city explorer. On the downside, the UMPCs proved only partially suitable for outdoor use. Firstly, the readability of the displays was greatly restricted in direct sunlight. Although increasing the contrast made it easier to read (which, however, reduced the overall battery life-time considerably), readability was still significantly restricted. To cope with that problem, test users had to, if possible, search for more shady places to view the display. Another problem was the limited battery-life, which was restricted to between 2-3 hours of operation. While most users in fact did not want to spend more time exploring the city, battery-life still remained a major technical limitation.

## 5.2 User Experiences

As mentioned above our main research interest was to a) investigate how users can be encouraged to experience the (physical) authentic cultural heritage with the aid of rich multimedia content delivered via location-aware mobile technology and b) learn how this impacts the way in which users navigate through the physical environment.

A key lesson from the user trial in encouraging users to actively engage with the physical heritage is that cultural heritage content should be presented as lively, varied and interactive as possible. In this respect users particularly praised the fact that the mobile city explorer enabled them to find the city's "hidden treasures", i.e. uncommon and unusual facts and stories that they were not previously aware of (such as the history of a still existing or former tavern or brewery). But also unusual themes or approaches to themes can raise users' interest in engaging with the physical heritage, as was shown in the Latin Inscriptions theme. In this theme users were promoted to find Latin inscriptions on buildings and monuments throughout the historical city. The mobile explorer gave hints about their meaning and provided translations and their historical context. Many users, for example, noted that although they had walked-by some of these inscriptions on almost a daily basis they were not present in their conscious experience of the city. In the Historical Windows and Doors themes, on the other hand, users were encouraged to find specific doors and windows. This task required users to examine historical buildings up close, thereby gaining a very different perspective on this unique built heritage.

Users also appreciated the mix of "high culture" themes with anecdotes and everyday stories. The different nature of the themes and their different storytelling approaches offered something for everyone. For example, while some users particularly enjoyed the more traditional themes (i.e. Georg Trakl, Latin Inscriptions) others focused more on the anecdotes and tasks as presented in the Historical Breweries, Taverns and Hotels or the Historical Windows and Doors themes.

Text length and style of writing was another key factor for actively engaging users. The (text) length of the stories presenting each theme was considered appropriate, neither too short nor too long. A few users, however, criticized that a few texts were still either too academic in style, or too long or too short if the subject was particularly interesting. Users also

appreciated the fact that for all contents metadata and copyright information were provided.

A major focus of the mobile explorer was placed on interactivity, providing not only various interactive features, but also encouraging users to actively create and share content with other users. In the Salzburg city explorer several interactive features were offered:

- Various exercises, tasks and games (e.g. visitors were invited to complete selected verses of a poem or guess the meaning of Latin inscriptions);
- Interactive quiz (i.e. visitors could test their knowledge of the main bridges over the Salzach; visual and audio feedback enhanced the experience);
- Creating and sharing of content (e.g. visitors could state their impressions on specific Georg Trakl poems and compare them with the interpretations of other users);
- Image enhancement (each image could be enhanced to full-screen, thus allowing users to study the individual images in detail);
- Scavenger hunts/geocaching (i.e. visitors were requested to search for historical windows and doors in the city);
- Answering single/multiple choice questions;
- Hyperlinks, providing users with additional and related information.

Trial users particularly enjoyed the interactive features as they made it more interesting for them to explore the city and actively engage with the content/stories. Activities, such as having to look for historical windows or doors, encouraged users to look more attentively at the historical city and its characteristics. In this way the stories became more vivid, inspired Eureka moments and stimulated users' desire for further exploration of the city and its history. The interactive elements also provided a welcome change from the more "traditional" forms of content presentation. For instance, many users noted that exploring the city in the form of a quiz or through searching for historical windows and doors was fun. Users also remarked that the interactive features enhanced the learning effect and made it more likely that they would savor the experience. Younger test users (<18) particularly enjoyed the interactive features, such as performing the quiz on Salzburg's bridges or searching for specific windows and doors in the city. They focused mostly on these interactive activities and largely avoided the non-interactive and more "high culture" themes (such as Georg Trakl). Users also liked to comment on selected Georg Trakl poems and view other users' impressions to compare them with their own ones. The only criticism in this respect was that users wished to have more opportunities in creating and sharing content than in the current version. Users also suggested including team activities to increase social interaction and communication with other users.

The 2007 user trial also reinforced our initial assumption that users tend to create their own exploration paths through a city rather than follow pre-selected thematic trails, when given the option. Users particularly appreciated the system's dynamic, multi-relation narrative/navigation system, as it allowed them to explore the city based on their personal preferences rather than having to follow one of the thematic trails. In fact, all 15 test users choose to dynamically navigate through the city, i.e. to oscillate/jump between themes; none of them explored the city

in a “classic” theme-by-theme approach. Although users had their favorite themes, they usually never stayed for long within one theme before they jumped to the next one. However, they also tended to return to their favorite themes from time to time.

How users created their paths differed from user to user. For instance, some users (especially those who were historically and culturally interested) preferred to create thematic and epoch related links between points of interest of different themes, while others preferred to visit points of interest in a (geographic) step-by-step approach, i.e. after having visited a point of interest they would check for other nearby attractions. Indeed, users often quickly discovered their favorite “navigational buttons”. By far the most popular navigation element was the “globe” icon, which showed points of interest that were geographically nearby. People who did not want to walk too far also often used this feature. How users navigated through the city depended partly on user preferences (e.g. some users favored historical or cultural themes, others the more playful and interactive features), but often equally important were stimuli from the physical surrounding or the stories they read (thus raising sudden interest), or even momentum and personal mood (e.g. a user would be too tired on a particular day for a “high culture” theme like Georg Trakl). Environmental conditions (e.g. bad weather) and the physical environment (e.g. users tried to avoid places that were heavily frequented by tourists) further affected users’ navigation approach through the city.

## 6. CONCLUSIONS

This project paper presented the Salzburg Mobile Explorer, an innovative mobile application for the Historical City of Salzburg, with a focus on mediating cultural and historical information in an experiential learning environment. Our main research motivation was to a) investigate how users can be encouraged to experience the (physical) authentic cultural heritage with the aid of rich multimedia content delivered via location-aware mobile technology and b) learn how this impacts the way in which users navigate through the physical environment.

The lessons learned from building the application were numerous. From the content preparation side, the iterative writing and rewriting process was particularly laborious. Texts had to be adapted towards the requirements of the end device and mobile use—i.e. texts had to be short and easy to read. This phase of preparation was severely underestimated and remains a major lesson for the future that the creation of meaningful content requires sufficient project resources. This project also demonstrated the varied challenges faced when integrating novel and emerging technologies.

Integrating the localization services proved an obstacle in the technical development process. The initially favored solution to utilize GSM interpolation technology did not prove feasible as local telecom providers either did not provide this service, or the service was insufficient in accurately localizing the user position. The solution finally chosen, GPS localization, proved to be quite effective and easy to implement, however the GPS performance was at times poor, with the GPS signal sometimes being disrupted or even lost in narrow alleys and passageways. This application was sufficient for the trial phase however a mix of localization technologies would most likely need to be adopted to provide a robust market-ready solution.

The end devices were “nice-to-have” and sufficient for the trial phase, although a more mobile and user-friendly end-device with better battery performance will be required for a future market deployable solution. There is also a tendency with the launch of emerging technologies to overestimate their performance or even availability. This posed many challenges and even a reworking of initial concepts. For example the keyboard on the Medion UMPC proved too small and tedious in practice, so the user-generated content concept was reworked to focus less on text input.

The positive feedback from the user trials underscored our initial assumption that there is a value in presenting cultural heritage content in a lively and interactive format via mobile devices. For example, users particularly praised the fact that the mobile city explorer enabled them to find “hidden treasures” of their city, i.e. uncommon and unusual facts and stories that they were not previously aware of.

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# THE DIVINE PROJECT : INTERACTIVE VISITOR ACCESS TO ARCHIVE AND SCIENTIFIC MULTIMEDIA VIA NETWORKED HAND-HELD COMPUTERS AND MOBILE DEVICES

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**KEY WORDS:** WiFi, multimedia, video streaming, mobile devices

## ABSTRACT:

The DIVINE project was put together to help develop advanced technologies to deliver streamed interactive multimedia content such as video and high resolution imagery to wireless mobile devices via WiFi within a museum environment. Techniques for error correction, scalability and signal robustness were tested via the simulation of streaming of advanced H.264 video and JPEG2000 encoding. A prototype platform using these technologies has been deployed at the Musée du Châtillonnais in Bourgogne, France. The museum contains a wide range of artefacts, the centrepiece of which are the treasures from the 5<sup>th</sup> Century BC tomb of the Princess of Vix. Users can move freely around the museum spaces and interactively explore each object in unparalleled detail as well as the contexts and inter-relationships of the artefacts. High resolution scientific imagery, archive video of the excavations, audio commentaries and explanatory text are available to visitors via ultra portable computer, PDA or smart-phone through a dedicated optimized WiFi network.

## 1. INTRODUCTION

### 1.1 Motivation

The aim of the DIVINE project is to give the visitor access to rich interactive multimedia on the objects on display within a museum. The system aims to provide location-aware access to a wide range of archive material not usually available to visitors. These include video and audio footage, high resolution scientific imagery such as X-rays, infra-red, raking light, multispectral imaging and 3D models. The goal was to move beyond simple audio-guides and allow visitors access to rich content in a flexible way through heterogeneous mobile devices. Devices such as hand-held computers, PDA's and smart-phones are becoming increasingly common and pervasive and have the potential to greatly enhance museum visits. As these are mobile devices, access to the large quantity of content must be via wireless networking. But in order to do this, various technical issues related to network scalability, error-handling and signal robustness have to be addressed as well as the incorporation of advanced coding and streaming. The aims of the project are not only technical ones, but also included some important for cultural heritage.

### Enhancing the Visitor Experience

Museums are beginning to acquire archives of video, audio, high resolution imagery and 3D models related to the works of art on display. However, much of this multimedia content is rarely made available to the visiting public. In addition, there is often high quality scientific content that has been produced during examination or restoration of works. For example, X-ray, infra-red, raking light or multispectral imagery. Such background content can greatly enhance the visitor experience, giving insights into the design, production, use and restoration of museum artefacts. Visitors can also benefit from being able

to interact and explore in a non-linear way the contexts and inter-relationships between objects, including related objects that may not even be part of the museum collection. Interactive visualization tools can allow users to manipulate, view aspects of the object normally impossible to see and to zoom into tiny details etc. Moreover, background information such as geographic, chronological or thematic contexts can turn a portable device into a specialized mini-encyclopaedia. Thus, visitors do not simply passively view or learn about objects, but also understand them in a more profound way, thereby bringing the objects to life.

Furthermore, such a system can enable advanced kinds of applications such as guided multimedia broadcasting, whereby a group guide or teacher can direct the visit and explore objects and zoom into details with the pupils simultaneously receiving the live broadcast.

### Museum Benefits

Archive material is often not only not readily available to the visiting public, but not even to the museum staff themselves. Old documents or photos can contain valuable information for, for example, restorers, but unless they are indexed and accessible, they may never be consulted. This is particularly true of objects sent away from the museum for restoration where background information that could be crucial may be missing.

The introduction of such mobile connectivity within museums will also provide an impetus to digitize archive material and re-evaluate their digital collections. Material that may have not been seen for many years can be rediscovered and brought back to life. It is also a potentially useful and powerful means for museums to communicate directly with the public and can provide an intelligent tool to help diffuse knowledge.

## 1.2 State of the Art

Various attempts have been made to provide similar multimedia services in several museums (Schwarzer 2001). Notably, in the United States, at the Smithsonian, the Museum of the Moving Image and the Whitney (Twidale 2000), who have used mobile devices for special exhibitions. The San Francisco Museum of Modern Art have also supplied visitors with iPaq's containing archive documents and video to help enrich a selection of works within the permanent collection. The Exploratorium, also in San Francisco, for a special study, used infra-red to link PDA's to provide content for several works of art (Amirian 2001). The Experience Music Project in Seattle is a part of its regular visitor experience and uses CD-based devices providing content related to its permanent collection (Woodruff 2001). Another interesting study took place at the Blanton Museum of Art, part of the University of Texas in 2003. The museum, in conjunction with the university IT department created the iTour, a three month experiment into interpretive technology (Manning 2004). This was an interactive PocketPC based handheld museum guide containing rich content including newly commissioned videos of artists and curators, textual information, and creative play components. Between 2005 and 2007 the Vancouver Museum of Anthropology installed the *VUEguide*, a handheld multimedia device with curatorial on demand video, audio, graphics, and animation that provided personalized, location-aware, rich media interpretation. Within Europe, several EU-funded projects have attempted to provide rich content via mobile devices. The MATAHARI project (MATAHARI 2002), for example, used mobile phone technology to provide audio commentary around archaeological sites. A further example was the Stratis Eleftheriadis Teriade Museum/Library in Lesvos, Greece where a prototype PDA system was put together for the *Fables* exhibition in 2005 (Micha 2005).

In recent years, several WiFi enabled systems have been trialed. The Tate Modern Gallery in London has conducted trials from 2002 onwards on multimedia tours (Wilson 2004). These tests were initially based on WiFi enabled Toshiba e750 PDA's and featured audio, image, map and even gaming content. The feedback to the trials were highly positive. An experiment at the Royal Abbey of Fontevraud, France (Fontevraud Royal Abbey 2006), used WiFi to supply PDA's with audio, video and text. The most recent, though, is the Grand Versailles Numerique at the chateau de Versailles in France (Grand Versailles Numerique 2007). This uses a combination of web-based content, virtual reality and video available via WiFi or podcast to not only enhance a visit to the site itself, but to also provide content to remote users. The Louvre itself has also upgraded its audioguides to add visual multimedia content, themed tours and maps (Musée du Louvre Multimedia Guides 2008). The system, however, stores the data within the touch-screen hand-held device itself.

## 2.PROJECT OVERVIEW

### 2.1 Project Consortium

The DIVINE (Diffusion de Video et Image vers des termiNaux hEterogenes) project is a French national research project. It consists of a consortium of partners, each bringing unique skills and experience to the consortium. The partners include cultural heritage institutions, such as the Centre de Recherche et de Restauration des Musées de France (C2RMF). The C2RMF is

the national restoration and research centre for museums housed within the Louvre museum. It undertakes scientific studies and restoration of works of art for not only the Louvre Museum, but for around 1200 museums throughout France. The centre possesses a vast digital archive of scientific imagery, study reports, analyses and 3D model data. The centre has a high level of expertise in digitization and 3D acquisition of works of art. The other cultural heritage institution is the Musée du Châtillonnais, who provide the test and prototype environment for the project. In addition, there are several university partners such as LIP6 (Part of the Marie Curie University in Paris), ParisTech (a telecoms engineering school in Paris), INRIA (a computer research institute in Sophia-Antipolis) and ETIS (a signal processing laboratory on the outskirts of Paris) who have all a significant experience in video coding and/or wireless networking. Finally, there are industrial partners such as Thales, who have worked extensively in the video coding domain, both commercially and within research projects. In addition, Thales have also been involved in aspects of the JPEG2000 still image standard. Finally, Eona is a small SME specializing in video content management and distribution via dedicated set-top boxes.

### 2.2 Objectives

The basic objectives of the project are to test and evaluate video and wireless networking protocols, techniques and standards for multimedia use in a museum environment. The aim is to deploy WiFi to enable mobile computing devices such as laptop computers, ultra-mobile computers, PDA's and smart-phones to be able to access multimedia content in order to enhance to visitor experience and make scientific and archive content available to the visiting public. The project aims to adopt the most advanced technologies currently available and develop solutions to any problems encountered.

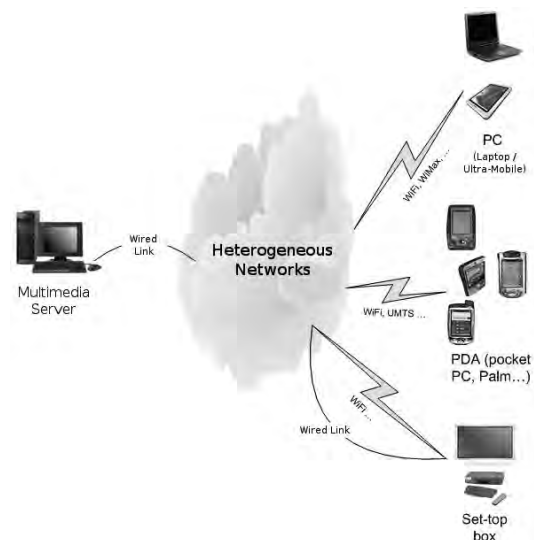


Figure 1: Network Schema

Mobile devices capable of showing video, audio and detailed images are now readily available. However, the volume of museum data potentially available is too great for it to be stocked locally on such a mobile device. Wireless networking is, therefore, required in order to deliver the multimedia content to the user, while allowing the user to move around the museum. This also allows for a certain degree of location-awareness for the client. For this project, networking is based on the WiFi

802.11g 54 Mb/s standard. Additional advanced techniques such as UDP multi-casting and multi-resolution streaming are used to allow large numbers of heterogeneous users to efficiently access the network simultaneously. The imaging and video content itself must also be adapted for wireless use. This necessitates their availability in a scalable format adapted to multi-resolution streaming, such as JPEG2000 for images and new high performance video codecs such as H.264/AVC and SVC. Various techniques for signal robustness have, furthermore, been adopted to make sure transitions between transmitters happen seamlessly and that there are no dead-zones within the museum. A specialized user interface installed on the mobile device allows the user to navigate between exhibition spaces, individual works of art or subject areas. The user can also navigate within the content itself, for example, allowing users to zoom into details of images.

An overview of the network schema can be seen in figure 1.

### 2.3 Methodology

The project consists of several key phases:

- The first is an evaluation phase in which various technologies were assessed for use within the project. Improvements and optimizations were also proposed and implemented.
- Secondly, there was a simulation phase which sought to evaluate, compare and thoroughly test the chosen technologies and the solutions developed within a complete model of the network environment. This simulation phase was an important prerequisite before deploying the final prototype system.
- In parallel to this, the cultural heritage partners were tasked with researching, retrieving, creating and digitizing multimedia content for use within a prototype system.
- A prototype system encompassing the technologies, developments and museum multimedia archive content would be assembled and installed within the host museum. This necessitated a radio survey of the museum building in order to establish the location of transmission black-spots, interference and signal power requirements.
- The resulting system will be evaluated and fine-tuned from both a technological quantitative perspective in terms of criteria such as data stream reliability, error rates and responsiveness. But also in terms of public usability through user feedback, questionnaires and face to face interviews of users.

### 2.4 Technology Choices

There were several technological choices and issues that needed to be addressed in order for interactive networked media streaming to be possible for potentially large numbers of simultaneous users:

1. Network connectivity would be based on the well-known 802.11 b/g WiFi and the 802.16 WiMax standards.
2. Scalable content: video and image streams had to be adapted for use on the varying sizes of screens available on devices ranging from laptop computers to smart-phones.
3. Efficient compression solutions: bandwidth would be limited, as would the memory capacities of mobile devices.
4. Streaming protocols: RTSP session connection initiation with an RTP multimedia stream payload over a UDP or UDP-lite transport layer.

5. Multicasting: allowing for highly bandwidth-efficient non-interactive broadcast or simulcast of media streaming to large number of users.
6. Contextual quality of service data (such as link transmission quality, available bandwidth, network capacity) communicated between the different blocks in the chain of transmission.
7. Network level optimizations at the different layers - transport, network and radio layers.

### 2.5 Video Stream Encoding/Decoding and Transmission

A key part of the project was to address the issue of high bandwidth video streaming over error-prone and variable link-quality wireless IP networks. Codecs and protocols need to be sufficiently robust to handle the inevitable packet loss and transmission errors without failing. As video is the most bandwidth-hungry type of content, particular emphasis was put on optimized encoding of such multimedia. The choice was made to use the high performance H.264\* standard in AVC and optionally SVC mode, wrapped within the UDP-based RTSP/RTP streaming protocol. Video streaming provided the focus for the simulations and numerous combinations of protocols and techniques were evaluated. These included error correction techniques based on Reed-Solomon and Fountain Codes (for example, LT or Raptor) as well as comparisons between the UDP and UDP-lite protocols. Joint source channel decoding was also tested for use in enhancing transmission robustness. Also included were comparisons between unicast and multicast broadcasting. The simulations measured the impact of the various protocol layers (transport, network and radio layers) at various distances (between 50m and 150m) from the WiFi access point and looked at numerous factors such as:

- the number of connections per access point
- the average bitrate per user
- the maximum packet delay
- video packetization protocols
- network reliability and packet loss rates
- transport layer overheads
- stream quality at different resolutions in the presence of various levels and types of data loss.

The simulations were carried out using test harnesses bootstrapped to the open source OMNET++\* simulation platform.

### 2.6 Image Streaming

The viewing of high resolution imagery was another key component of the project. There were two main methods employed.

#### Multi-Resolution Tile Streaming

The first method of image streaming is a tile streaming based technique used by the open source IIPImage platform (Pitzalis, Pillay, Lahanier 2006). In this system ultra-high resolution TIFF images are efficiently streamed to the client in the form of compressed JPEG tiles. In order to optimize this, the TIFF is structured in a tiled pyramidal layout which minimizes the load on the server. The client can zoom and navigate within the

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\* <http://www.omnetpp.org/>

image, but only needs to request tiles corresponding to the area of the image currently visible. In this way extremely large images of up to several gigabytes in size can be instantly zoomed and navigated remotely with minimal hardware requirements on the client. Furthermore, the platform handles high dynamic range, colorimetric CIE L\*a\*b\* and multispectral images. In order to extend the IPIImage platform to mobile devices, new clients were created specially adapted to the limited display areas and interfaces of such devices.

The IPIImage system has been in use for many years at the C2RMF and now also at the Musée du Châtillonnais. Via the EROS database (Lahanier, Aitken, Pillay and Pitzalis, 2005), users have access through IPIImage to a quarter of a million high resolution scientific images.

### JPEG2000

The JPEG2000 format is a wavelet-based encoding that is not only more efficient than JPEG, but is also capable natively of streaming based on image quality or resolution. In order to facilitate streaming there is, the JPIP (JPEG2000 Interactive Protocol - Part 9 of JPEG2000 Protocol - ISO/IEC 15444-9) interactive protocol, which enables random access to tiles within the JPEG2000 code stream. Furthermore, the JPWL (JPEG2000 Wireless - Part 11 of JPEG2000 Protocol - ISO/IEC 15444-11) wireless standard is designed for unreliable wireless networking and contains techniques, such as redundancy or interleaving, to make a code stream more resilient to transmission errors. These protocols were tested in the simulator multiplexed with the heavier video traffic.

## 3. PROTOTYPE

### 3.1 Musée du Châtillonnais

The Musée du Châtillonnais in Châtillon-sur-Seine, Bourgogne, France was chosen for the richness of its collection which ranges from objects from the first iron age to paintings from the 19th century. Its most famous object is the "Vase de Vix", a 2m high bronze vase discovered buried within the tomb of a 5th Century BC Celtic Princess. The museum is an important one for anyone wishing to understand the Celtic and Gallo-Roman history of France. The collection reflects the rich heritage of a region situated at the edge of the basins of the Seine, Rhine and Saône rivers. It represents a junction between the Mediterranean and the English Channel.

The museum was previously housed within a 16<sup>th</sup> century manor house in Châtillon-sur-Seine, but was in the process of transferring its collection to a nearby newly refurbished and partially rebuilt Renaissance-era abbey (Figure 2). This, therefore, provided a perfect site and opportunity for the installation of a system prototype, as various electrical or networking cabling and exhibition space layout details could be conceived with the wireless multimedia access system in mind. The visitor will be greeted by the ancient cults of the river sources, of which the Douix de Châtillon-sur-Seine is the symbol. The stone ex-votos reveal the religious practices of the ancient Châtillonnais. Through its new layout, the future museum will exhibit different facets of the cultural, natural and economic life of the region. The multimedia content that the museum director wishes to develop will seek to integrate these various aspects. This new museum aims to fully embrace new technologies that enhance the visitor experience and that aid the public to better understand the works on display.

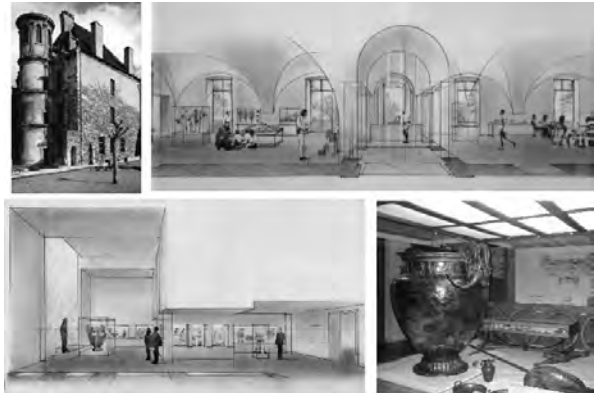


Figure 2: Montage showing the old museum building (top left), the new exhibition spaces (top right and bottom left) and the Vase of Vix (bottom right)

### The Tomb of the Princess of Vix

The centrepiece of the museum collection is the exceptional collection of artefacts from the Celtic tomb of the Princess of Vix. The princess was buried at the foot of Mount Lassois at Vix, near to present day Châtillon-sur-Seine around 2500 years ago. This tomb is a unique archaeological discovery in Western Europe containing unrivalled gold jewellery (figure 3) and the famous bronze vase, the *Vase of Vix*, a gift from the Greeks of Southern Italy. The giant vase was probably made in the Sybaris, Metaponte region and has a height of 1.64m and an internal capacity of 1100 litres, making it the largest bronze vase known from Antiquity (figure 2 – bottom right). The volume is close to that mentioned by Herodotus in *Histories 1 70* referring to an exceptional present from the Lacedaemonians to the king Cressus. It is linked to the tradition of the Mediterranean banquet and allowed the mixing of water and wine which was filtered before consumption by the guests. This hypothesis for its use is confirmed by the presence in the tomb of an Etruscan cruche (oenochoe) and two Greek ceramic cups. The presence of this extraordinary piece demonstrates the exceptional richness of the Châtillonnais region during the first and second iron age and underlines the close links that existed between the Mediterranean world and the continental Celtic kingdoms both on a commercial and cultural level. It is a symbol without equivalent in proto-historic archaeology.

### 3.2 User Scenarios

The prototype allows the user to freely roam the museum and access video footage and high resolution imagery of various works from the museum. Nevertheless, several specific scenarios were developed to cater for different kinds of users and their needs.

#### User Types

For the prototype, two user types were identified. Namely, regular museum goers who have a certain level of prior knowledge of the works and who wish to have access to detailed information and be able to relate the works to their prior knowledge. And secondly children of secondary school age, who are highly technology literate and to whom the idea of exploring a museum environment and of its objects via smartphone or other mobile device comes naturally. Aiming the prototype at these two very different types of visitor would push the system to its limits and demonstrate its flexibility and utility.



Figure 3: Golden Torque (195 x 213 mm, around 500BC) found in the tomb of the Princess of Vix. The top left image shows an overview of the object, top right a detail of the rounded end, bottom left, a tiny horse figure on the torque, bottom middle a detail of the base of the horse figure and bottom right an X-ray of the rounded end of the torque

#### Information Views

In addition to these user types, several types of views of the available information were envisioned:

- Exploration per object including image details, scientific imagery (Figure 3), explanatory text, video footage, contextual information etc
- Geographic views allowing the user to explore artefacts related by geography and physical proximity of manufacture or discovery
- Chronological views showing the distribution of objects in time rather than space
- Theme-based visits, (for example, funerary cults etc)
- Information on the surrounding region and the historic museum building itself



Figure 4: High Resolution Image Viewing on an HP IPaq PDA showing the X-ray (left) of a zoomed section of the Vase and the colour image (right)

#### 3.3 Digitized Museum Content

The project provided the opportunity for both the C2RMF and the Musée du Châtillonnais to re-evaluate and even rediscover archive material related to the artefacts on display. Like an archaeological dig, old unused analogue archive material was exhumed and brought back to life through digitization. In

addition, new content was created specifically for the project, including 3D models, explanatory texts and audio content. The highlights of these include:

- A high resolution 3D model made using a Minolta laser scanner. This was only possible because the extremely fragile vase was removed from its exhibition casing for transportation to the new museum building
- scientific images from the C2RMF's EROS database (over 200 high resolution images). The object was studied on-site in 1979 by the C2RMF and the results of the material analyses of the metal and the photographic and X-ray exams made for a report are available for consultation. Previous studies had also been ordered in 1981-82 and 1987 before the major exhibition 'Autour de la Dame de Vix' in 2003. In total over 700 objects have been inventoried and integrated into the database.
- images of the discovery of the object in 1953 and of its transportation and restoration
- aerial photography of the archaeological site, which is still being dug, revealing today the palace of the Princess of Vix
- extracts from television coverage of the object
- a rare radio interview made with the discoverer of the tomb dating from just after its discovery
- extracts from articles relating to the tomb of Vix (for example, Picard, Rolley and Haffner 2002)

#### 3.4 Uses for Inventory and Restoration

The museum staff now possess a useful tool for inventory and conservation purposes. The wireless network enables access to the all the analyses and restorations carried out by the C2RMF. In addition, various restorations and studies were carried out by private contractors, whose reports have also been digitized. The ability to access and synthesize this documentary content within the exhibition spaces themselves in front of works that cannot be easily moved has been of great use in terms of inventory management and conservation evaluation.

#### 3.5 Content Management

The CMS used for the project is based on the MRS content management system developed by Eona for its video distribution and set-top box system. The ease of use of this system for the museum staff is an important factor, allowing easy insertion of new content and allowing conservators, restorers and librarians to be able to add and modify the system as necessary. This ease also means that the system can continue to be maintained independently by the museum staff after the end of the project.

#### 3.6 Prototype Evaluation

The installation is currently being tested via signal-strength measurements and quantitative studies showing error rates and transmission robustness with respect to various network loading conditions. In addition, user surveys in the form of questionnaires and interviews are to be carried out to evaluate ease of use and utility to the visitors. The feedback will be used to further improve the visitor experience and extend functionality. Feedback data from the devices themselves can also indicate those features most used or accessed. This data will be used to further optimize the content and functionality.

Users will include not only the two user types described previously in section 3.2.1, but also the public in general as well as the professional museum staff who will need to maintain the system in the future.

#### 4. FUTURE WORK

##### 4.1 User Contributed Information

A potentially significant use is in further enhancing the visitor experience through the use of user annotation, tagging and taxonomies. Combined with social networking techniques, visitors will be able to not only receive information on works of art, but also to contribute to the mass of information available.

##### 4.2 3D Model Streaming

The project restricted itself to the analysis of streaming techniques for multimedia content such as high resolution imagery and video. However, museums increasingly possess 3D model data on their objects. Such modelling provides the means to interact and manipulate objects that may be too fragile to move or touch. As such they are an important part of the multimedia repertoire of museums. High resolution models, however, can become prohibitively large and computer-intensive for use by mobile devices or even basic desktop computers. Techniques for the generation and transmission of multi-resolution models are crucial if such data is to be made readily available to mobile clients. Further research must seek to address this issue if they are to become pervasive.

##### 4.3 Legacies

The technical solutions developed will be re-used in further related projects by several partners. The C2RMF will continue to assemble the documentary sources (historic, scientific and restoration), digitize the images in high definition and extract and index the text. The expertise gained will allow the C2RMF to transfer the technology to other museums who wish to embark on such a course. The new Musée du Châtillonnais will open in June 2009. Although the project will have terminated by then, the museum is keen to maintain and continue to use and enrich the system with new content. Furthermore, in order to help finance the maintenance of the system they are interested in offshoot applications such as print-on-demand services as well as seeking sponsorship or grants.

#### 5. CONCLUSION

The DIVINE project has tested and evaluated techniques for the wireless streaming of diverse multimedia content ranging from high resolution scientific imagery to video footage. A prototype platform has been installed in the Musée du Châtillonnais, allowing visitors to freely roam the exhibition spaces and interactively explore each object in unparalleled detail as well as learn about their background contexts and inter-relationships. In addition, several user and viewing scenarios have been created to help visitors better understand the works on display. Professional applications of the technology for museum curators and conservators have also been developed.

The project forced the Musée du Châtillonnais and the C2RMF to search for old archive material, undertake further research on these documentary sources and digitize this archive material.

The resulting multimedia content has been made available to the public through the prototype.

Such a system not only enhances the visitor experience, but by bringing the user closer to the museum and its works, visitors can feel themselves as a part of the institution and gain a sense of ownership of the institution and artefacts within it. The creation of such links between the museum and the public will help to preserve and strengthen such precious cultural heritage.

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# **VR and 3D Modeling**



## DIGITAL OCEAN: A NATIONAL PROJECT FOR THE CREATION AND DISTRIBUTION OF MULTIMEDIA CONTENT FOR UNDERWATER SITES

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**KEY WORDS:** R&D Project, Multimedia Collection, 3D visualization and modelization, data acquisition

### ABSTRACT:

In this paper, we present a national R&D project, DIGITAL OCEAN<sup>1</sup>, which is a system allowing the distribution of submarine multimedia content resulting from the integration of three modules: an underwater device for multimedia content display, a software for virtual environments edition and a demonstration video game. These three modules constitute the project's main components. In fact, four partners are involved in the development of the project, each handling specific aspects of it: RATC team of IBISC<sup>2</sup> works on *Oce@nyd* for the digital media collection on the internet, which is a groupware architectural model based on Web services and software agent's integration, bringing a new approach for creating collaborative applications and innovation to the CSCW domain. The I&M team of LSIS<sup>3</sup> takes part in the design of the *Oceanyd* software that allows a real-time sea-beds visualization along with a data editor interface. Using a popular open-source graphics engine, an underwater virtual environment is created and composed of several fauna and flora specimens, and rendered with effects such as water plane reflection, skybox, lights, etc. Another partner, SEMANTIC-TS<sup>4</sup>, provides the Digital Elevation Model (DEM) for creating virtual sea-beds, along with measurements concerning underwater acoustics, oceanography measurement data and signal processing. Finally, VirtualDive<sup>5</sup>, the company that has created the project and handles its overall management and marketing. This project constitutes the company's unique activity, so its commitment to the project's success is total. The company has a global vision of the project, where it should be directed at short and long term but also a comprehensive view of all project details and of their evolution in time.

## 1. DIGITAL OCEAN

### 1.1 Presentation

Two thirds of our planet is covered by oceans. This space of silence, that is fragile but wonderful, where humanity's destiny may be determined, is almost unknown by the general public. Using virtual and augmented reality, interactivity in 3D environments and perceptual immersion, animation in real time and collaborative modelling, the objective of the project DIGITAL OCEAN is to offer to humans, the possibility of navigating like fishes, through submarine environments, dematerialized and distributed by high speed internet.

VIRTUALDIVE, the company that created the project and the team leader, is developing three pilot sub-projects: TRYTON, an underwater display apparatus, OCEANYD, submarine sites editing computer software and NAUTILUS QUEST, video game in immersion. These projects, inter-related but autonomous, are at the prototyping phase for the equipment, and at the modelling phase for the software and the game. The target of DIGITAL OCEAN is the full integration of those projects into a unique multimedia underwater system. To reach this objective, we created a multidisciplinary and well balanced partnership, with complementary experiences and competences,

located in France. In fact, the partnership is composed of two public research laboratories, LSIS of the University of Aix-Marseille II and IBISC of the University of Evry, along with two small and young corporations, SEMANTIC, based in Sanary and VIRTUALDIVE located in Marseille.

In this paper, we aim at giving a global view of the project, along with project's organisation between the partners, the research and development progress, as well as the lessons learned from this project that constitutes a truly innovative system for discovering the underwater world. We will proceed as follows: in the first section, we talk briefly about tasks' division, research and development concerns between the partners, as well as a description of the partners' competence in achieving the tasks given to them. In the second section, we talk in more details about the three-subprojects that constitute DIGITAL OCEAN. In the third, fourth and fifth section, we will explain the work done by every partner respectively in the context of DIGITAL OCEAN, as well as a scenario of use between the different parts of the project in section five, and how they interact together in order to build the global project. In the sixth section, we conclude and discuss the perspectives and future work to be done.

## 1.2 Project's Partnership

The DIGITAL OCEAN project is divided into four subprojects. Two groups of experts in the two research laboratories will assume the management of the first 2 subprojects, along with SEMANTIC-TS and VIRTUALDIVE, the 2 companies that will assume the management of the other two sub-projects, all of which are at the core of RIAM ("Réseau pour la Recherche et l'Innovation en Audiovisuel et Multimédia") 2006 thematic, that is supported by the National Agency of Research in France (ANR):

- Monitoring the process of dematerialization - constitutes subproject I, managed by LXAO team of LSIS laboratory and concerns the rebuilding of digitalized sea bottoms.
- Interoperability and Tailorability - constitutes subproject II, managed by RATC team of IBISC laboratory, and relates to the compatibility of different interfaces and assures eventually the integration of the three pilot projects into a single multimedia product.
- SEMANTIC, that is a signal monitoring specialist, will take over subproject III aimed to develop a method of digitalization and geo-positioning of sea beds, as precise, fast and economical as possible. Coupling vertical acoustic detection by sonar with lateral sonar installed in a ship that is easily transported by road, while associating photo and video, they crystallize on 3D referential, the submarine topography of any off-shore site in the world.
- VIRTUALDIVE, the team leader and creator of TRYTON, OCEANYD and NAUTILUS QUEST, is being committed for three years of R&D and prototyping of these projects. They enter the phase of uses evaluation and ergonomics testing that precedes market introduction planned for beginning of 2007. It seems thus essential to insure the continuation of the research and innovation process under way and to foresee as far as 2011. With this in mind, the company brings to the partnership the results already achieved, and holds the responsibility of subproject IV, which includes the overall coordination, monitoring and direction of DIGITAL OCEAN.

In fact, this project will be accomplished within 37 months, while the financial aid requested is up to 473.000 Euros, out of which 330.000 Euros are intended to the research laboratories. Moreover, human resources that are mobilized specifically for the project, represent 66% of the aid amount. Moreover, the partner corporations give the precompetitive calling to the project and provide for its industrial basis. Furthermore, as both took considerable risks by engaging in cutting-edge technologies related to the sea, these corporations are bringing to the project the required credibility and increase its success chances. They anchor the project in the industrial and commercial network of operations centred at Ile-de-France and PACA regions in France.

## 1.3 Concepts and objectives

The company (VIRTUALDIVE) initiated Digital Ocean three years ago. The founders of the company invented the concept, developed and patented the submersible device *Tryton*, copyrighted the software *Oceanyd* and the video game *Nautilus Quest*, where these modules constitute the project's main components. This project constitutes the company's unique activity, so its commitment is total to the success of the project.

The company has a global vision of the project, where it should be directed at short and long term but also a comprehensive view of all project details and of their evolution in time.

Digital Ocean aims to take up the challenge of "opening, to billions of people worldwide, access to ocean depths, at anytime, anywhere, at no cost". Nowadays, these people can just perceive the changing surface of their sea shores, but ignore almost everything on what it hides. Since the beginning of times, ancestral fear, obscure anxiety and instinctive ignorance, antagonize people and ocean blue depths, earth's final frontier, that probably conceal the keys of human destiny. In fact, discovery and knowledge of underwater world may drive people into playing a more active role in the solution of problems facing our global environment, where oceans represent 71% of it all, but where those that know their depths – divers and marine scientists, represent less than 0,5 % of world's population. Who knows that oceans contain 97% of planet's water, determine its climate and weather generate most of the oxygen of the atmosphere and provide home for most of the life on earth? The obvious answer explains why oceans were so grossly neglected by our societies. Instead of bringing people to undersea, we need to do the opposite.

For the first time, navigating freely thorough the undersea, unrestricted and boundless, a desired activity that few may have ever accomplished, is now feasible and open to all people with the use of new technologies and their innovative applications. In fact, there is a need for offering to the public ways to discover by themselves, how oceans – earth's fragile life support system, are being irreversibly polluted and impoverished. Before the threat of desertification of ocean becomes real, it is imperative to digitalize them. This concept shaped the project Digital Ocean, where its long term objective is to digitalize, with small intelligent underwater robots around the world, representative seafloor sites in 3D imagery, then use the information on such sites to edit interactive virtual animated environments that integrate submarine video games and audiovisual contents off the shelf, diffuse it all, on-line etc., in real time, when possible. Consequently, people on pools and beach shores, through a network of dedicated submersible simulation devices, will be able to experience multisensory diving, on those distant sites. Thus, an uninterrupted virtual space is created, as realistic as fast changing technologies will allow. For those billions of people connected to the internet and who will never dive, virtual diving offers a unique alternative to real diving that is immediately available, without a cost and definitely safer than real diving. With this new system, the sea becomes transparent to all, giving means for human beings to see and learn about unknown spaces. Therefore, the critical link between the ocean and society is then re-established forever.

## 1.4 Project's innovation and market aims

DIGITAL OCEAN is aimed to people that may never practice diving but that are interested, if not fascinated, by the beauty and mysteries of oceans. In other words, it concerns 99.3 % of world population and is opened to various users' communities:

- Children and youngsters that will discover the ocean bottoms on line, through games and adventure,
- Divers that will be able to find, anywhere and instantly their preferred diving sites,
- General public that will experience in immersion, in a common swimming pool and by multi-sensorial simulation, feelings comparable to those of a diver touring the oceans' finest spots.

The clients targeted by priority are the owners of swimming pools, public or private – tourism hotels, attraction parks and

camping sites. They will be able to convert their pools into a space of multimedia display and animations. Hence, the project offers a very important potential to be used worldwide without the need to be physically in the sea.

DIGITAL OCEAN is a unique product, which its intellectual property is well protected internationally, by four patents and copyrights. It presents excellent perspectives of scientific, technical and industrial developments, innovation spin-off from the fast stream of new technologies: new distribution mode, 3D digital imagery, haptic interfaces, perceptual simulation, bone sound transmission, LED monitors, 3D stereoscope, behaviour modelling, etc.

Under present geopolitical environment, DIGITAL OCEAN attempts to reconcile the general public with the underwater world, to demystify and to personalize it, placing it at hand everywhere – that is on line. The public, eventually aware and educated, will travel freely and without any constraint, in this new and boundless space, and also throughout time, by the effective use of new technologies. Hence, the natural heritage hidden in the ocean depths will thus be known and protected.

We will proceed by explaining in more details the three sub-projects constituting the project DIGITAL OCEAN.

## 2. THREE SUB PROJECTS

### 2.1 OCEANYD

The *Oceanyd* concept is thoroughly original. It includes a feature that increases considerably the perimeter of its application by allowing the generation of 3D underwater “sketchy sites” from data already available in the market (publications, literature, divers’ reports) – previous to any mobilization of underwater data collection equipment. Some 50.000 submarine pictures, slides, videos, maps and drawings are available through Digital Ocean associates, to constitute the initial *project’s data base*. The “wiki process” can generate submarine 3D outlines easily, at minimal costs, delaying the actual underwater collection until economically feasible. The editing sequence is summarized in Figure 1 below:



Figure 1: Wiki-generation of 3D underwater site outlines

### 2.2 NAUTILUS QUEST

*Underwater videogame*: A model of a fully underwater video game was developed by Virtualdive and is available as background. There are few video games, such as those produced by Nintendo, which action develops underwater. But we didn’t find any production entirely conceived for the submarine environment and that aims to create a realistic simulation of the environment, integrating *actual diving sites* bathymetry and linking these sites in order to build a submarine video gaming network. The concept of deploying, in real diving environments, the game story line is also thoroughly innovative. *Nautilus Quest* has these features. This game will be further developed

within the frame of the global project, financed by potential end users.

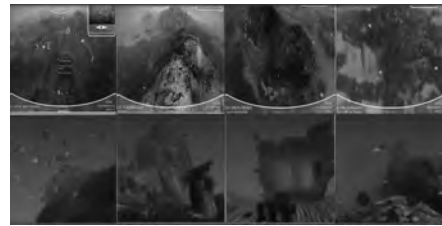


Figure 2: Nautilus Quest

### 2.3 TRYTON

*Submersible multimedia visualization equipment*: There are recent developments to extent the use of computers and computer components, such as a mouse, to underwater uses. There is no example of an underwater computerized display system conceived for swimming pools, associating video game, joysticks and multisensory simulation. The visualization – *in immersion*, of underwater contents, integrating virtual and mixed reality, breaks new ground in multimedia applications. The aim of this display is, hence, to visualize underwater environments loaded using the *Oceanyd* application, and be able to navigate freely in these environments using embedded joysticks, giving people the illusion that they are in a deep underwater site in a particular ocean. One of these equipments *Tryton* and the dedicated content *Nautilus Quest*, are just reaching the initial commercialization phase. We can see *Tryton* in Figure 4 below:



Figure 3: TRYTON

In what follows, we will discuss in more details the task of every partner in the project in order to converge to a unified and global DIGITAL OCEAN.

## 3. SEMANTIC-TS – OBJECTIVES AND ROLE

### 3.1 Objectives and role

SEMANTIC TS is a French company specialized in acoustic oceanography, which means using sound to infer the ocean. Relating to the project, SEMANTIC TS takes over subproject III that is aimed to develop a method of digitalization and geo-positioning of sea bottoms, which should be the most precise, fast and economical method possible. To do this, coupling vertical acoustic detection by sonar with lateral sonar that is installed in a ship and which could be easily transported by road, while associating photo and video, they crystallize on 3D referential the submarine topography of any off-shore site in the world.

### 3.2 Work Progress

Experimentation phases were carried out using SEMANTIC survey vessel devoted to bottom inferring, in order to acquire

signals reverberated by the bottom. To do this, few methods have been carried out:

**3.2.1 DIVA method:** The first stage was to extend the innovative echo sounding method, DIVA, which is developed by SEMANTIC-TS to detect vegetation, taking more in consideration the presence of rocks.

The principle of the DIVA method is shown on Figure 4a. In fact, the shape of the acoustics' bottom impulse response from a scientific echo sounder is recorded simultaneously with a centimetric GPS position. Moreover, as the sand and the vegetation have different acoustic signature shapes, we have developed a signal processing algorithm based on discriminate analysis and energy level of the bottom that reflects impulse response. Figure 4b shows samples of sand and posidonia (genus of flowering plants) acoustic signature.

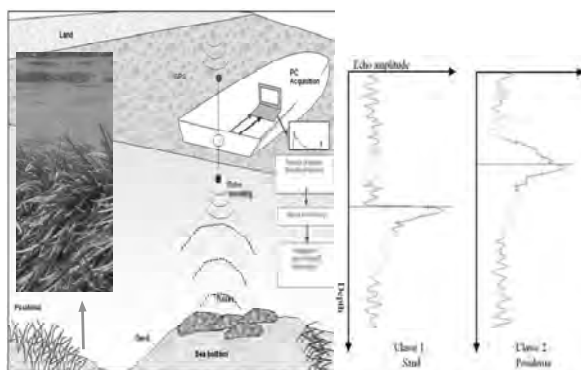


Figure 4: a- Principle of DIVA method. b - Typical acoustic signature of sand and posidonia

**3.2.2 Survey Systems:** Several systems were used on 4 diving places to make biocenose and bathymetric survey:

- Geoswath interferometric system, that is able to deliver bathymetry and, in very shallow water (less than 15 m) side scan sonar mosaic picture, with the frequency of 250 kHz.
- Echo sounding system, Simrad ES60 high precision (scientific system) devoted to SEMANTIC TS DIVA method for acoustic bottom vegetation detection.
- D-GPS differential RTK Leica GX1230 centimetric: one base and one receiver.
- Acquisition and processing data devices, and automatic navigation system.
- Help of Professional divers with video cameras.



Figure 5 shows principles of multisensor acquisition in shallow water on the SEMANTIC survey boat.

**3.2.3 Data fusion:** In order to produce precise 3D vegetation mapping, we have used on a second stage, a method based on the fusion of data provided by:

- Geoswath bathymetric system.
- Side scan sonar systems (Geoswath or Klein)
- DIVA method: Methods are operated simultaneously, and data fusion is realized by combining:
  - 3D bathymetric data producing micro relief information of the vegetation
  - Side scan sonar imagery in gray levels, producing information about reflectivity, and so about bottom nature.
  - DIVA information about presence and absence of vegetation.

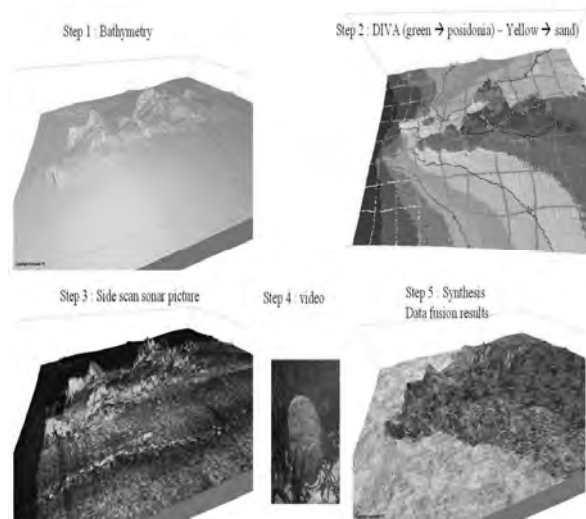


Figure 6: Figure placement and numbering

**3.3 Problem Solving and solutions considered**

The project DIGITAL OCEAN needs very accurate precision for measurements, implying using several high tech survey systems. Few main difficulties remain in technical problems that are usually generated by the data acquisition systems, which are very complicated to use and whose quantity of data needed for data fusion application are huge. To solve these problems we have developed specific GIS software that is able to process data inside the GIS itself.

**4. LSIS LABORATORY – OCEANYD R&D**

**4.1 Objectives and role**

In the scope of DIGITAL OCEAN project from VIRTUALDIVE, the I&M team from LSIS laboratory takes part in the design of the Oceanyd software. This software is notably meant to visualize sea-bottoms in real-time, integrating a data editor and configuration interface, thus designing a virtual dive spot.

**4.2 Bathymetric data**

Our partner in the project, SEMANTIC-TS, allows us to have one bathymetric map by spot, with biocenose information in supplement. The model provided is a Digital Elevation Model (DEM) represented as a raster, which means on one hand, the points saved are regularly distributed on x and y axis, and on the other hand, each couple (x,y) is associated with an unique

altitude  $z$ . The regular grid formed can thus be represented in many forms, while greyscale images of relief maps and triangulated geometric meshes of the surface being the two most employed types.

The data volume being often relatively important, terrain visualisation must be based on adapted methods. All follow the simple observation that the areas near the virtual viewer need to be rendered with full details, and, at the opposite, areas situated far away can be simplified.

### 4.3 Background

To study the feasibility of the project, VirtualDive contacted the I&M team in 2005. A prototype has been realized during a first internship in the context of a Master's, where some visual effects had been developed: volumetric fog, caustic, water rendering, etc... This version has identified the need to use an efficient visualisation algorithm.

In 2006, students of Master SIS (Sciences de l'Information et des Systèmes) - Information Science and Systems) (<http://www.lsis.org/~master/index0.html>) have developed a simplified version of (ROAM) from Duchaineau and al (Duchaineau, 1997), which has led to an improvement of performance and increase rendering effects.

At the end of the year 2006, the DIGITAL OCEAN project was supported by the ANR-RIAM ([www.agence-nationale-recherche.fr/](http://www.agence-nationale-recherche.fr/)), for a period of 3 years. This project, even if it cannot be regarded in the strict sense as a continuation of the previous developments, has undoubtedly benefited from the experience gained in previous work.

A new working prototype, which can be described as pre-version has been developed. In fact, it has been a showcase for the VIRTUOLDIVE Company during its participation in various events: Olympic week in Lausanne-October 2007, etc. The development of this prototype permit to test the effectiveness of an open-source graphics engine: (Ogre3D) (<http://www.ogre3d.org/>). On this occasion, beyond the effects already proposed (water rendering, skybox, etc.), new parameter editing functions of the site was added. In particular, it is possible to add the geo-localized photos by the team of Semantic-TS, or to place and resize few 3D models specimens of wild local aquatic fauna and flora.

### 4.4 Work in Progress

The Oceanyd architecture was designed to foster communication with Océ@nyd, which is responsible for collecting, via the web, information that will enrich the virtual model site, from users more or less privileged, while promoting aspects of tailorability and interoperability.

In addition, the nature of the data provided by Semantic-TS (DEM) appeared incomplete in terms of underwater context in which we stand. Indeed, by its very definition, the model provided does not represent excavations such as caves, holes, overhangs, etc, which are predominant in a dive.

At the moment, and due to the complexity of such a representation, no model used in real-time integrates intrinsically excavations. In general, representations of caves or overhang are obtained by adding 3D objects on the DEM. The design of a model and the associated visualization method, taking into account this specificity, and based on certain limits

in the representation, is a research axis that has caught our interest.

Our approach relies on a regular paving of the area of representation. Regular sampling on each of 3 axes gives birth to pavers in which a finite number of local configurations may register, constituting an "alphabet" of elementary cases (for example, a pad could be set to  $3*3*3$  units). The authorized combinations of contiguous cubes will be selected among those which approximate on a continuous way the surface to represent, minimizing locally the error.

The determination of the alphabet is therefore a first step in this method. Not only we have to retain a set of cases conducive to relevant combinations, which respect the simplistic constraints that one can give (for example, the surface to represent can go only once in a cube), but moreover, this alphabet must be able to be defined to different levels that correspond to the different levels of detail that will permit to design the terrain.

The correspondence between two levels of detail, i.e. the manner in which case a combination of a given level will be replaced by a single case of the alphabet in the level of detail immediately coarser, may be pre-established, as may also be pre-established the combinations generating continuous surface models, whatever the level of detail you are situated in.

To exploit the various levels of detail thus defined, we will have to generalize the (GeoClipmaps) concept from (Losasso and Hoppe, 2004) to fit the 3D definition universe in which we have listed our generic alphabet.

## 5. IBISC LABORATORY- OCE@NYD R&D

### 5.1 Objectives and role

The IBISC Laboratory handles the development and research concerns for the Océ@nyd sub-project, which constitutes the sub-project 2 of DIGITAL OCEAN. In fact, the participation of IBISC Laboratory began in January 2006, the official kick-off date of the project in Aix-En-Provence (France). The part concerning IBISC Laboratory, more specifically the R&T Team is the design and implementation of a new groupware architecture that satisfies the properties of Tailorability (Cheaib, 2008) and Interoperability, where it should support the integration of the various independant parts of the project into a cohesive entity, thus offering a high quality project intended to support various applications. This architectural model will contribute to the project DIGITAL OCEAN in different aspects, mainly:

- 1- Integrate the three sub-projects into a collaborative system that satisfies interoperability between heterogeneous applications.
- 2- Provide a collaborative system on the Web to collect and share multimedia files (images, audio/video, text descriptions, etc.) of underwater sites.
- 3- Tailor the services offered in the system with minimal human assistance, where new functionalities can be integrated dynamically without affecting the collaboration between users, and satisfy users' preferences depending on the task being done.
- 4- Create the link between the two applications, Océ@nyd and Oceanyd, where the files collected will be saved and then imported into the Oceanyd in order to enrich the 3D underwater environment with new and up-to-date files collected from divers or diving clubs.



In fact, a typical scenario would be when users (in our case, by user we mean divers or diving clubs) that are geographically distributed are using the collaborative platform *Oce@nyd* in order to collaboratively share their multimedia files to enrich the 2D bathymetric maps of underwater sites. At any moment, a user could prompt the system for a particular service (video stream etc, calendar, calculator, water temperature at a certain location, etc.). In case where this functionality does not exist already in the system, there must be mechanisms in order for the system to connect to the internet, search for this particular service that is deployed somewhere in public registries, and in case where the service that offers this particular functionality is found, the system should integrate it dynamically into the platform without affecting the other services in the system, nor the collaborative work of users in. Hence, a critical requirement in terms of flexibility, re-configurability and interoperability that impose this type of systems lead us to conceive a tailorable groupware architecture, that should be generic enough to support any type of systems, but its use and first prototypes will be mainly applied on the project DIGITAL OCEAN.

## 5.2 Need of a new tailorable groupware

In fact, with the advancement in computer entertainment and the apparition of Internet technologies, universal interoperability within collaborative applications is becoming a reality, while users geographically distributed people are highlighting the flexibility of cooperation by exchanging universally accessible services but often using incompatible applications that may lead to interoperability problems (Cheaib, 2008). As a result, the need for more effective means of collective collaboration is an extremely valuable area of research, while the demand increases for a framework to enable users to interact and collaborate based around mutual goals and shared data. However, most of these systems do not take in consideration the evolving need of users' to dynamically integrate new functionalities in order to enhance collaboration with others. In fact, making the system, its interfaces and the services that they could offer tailorable for users, is an essential and an ongoing research field that needs much attention to yet be concrete (Cheaib, 2008). In our work, we define tailorbility in groupware as follows: "a tailorable groupware is a collaborative system that can be dynamically (dynamic integration of new functionalities with minimal human assistance) or statically (the user can explicitly add functionalities to the groupware by extending its code) adapted to satisfy users' preferences" For this reason, tailorbility has shown to be an essential property that should be taken in consideration, as it offers to users the possibility to adapt the application based on their needs and preferences, and not the other way around.

In groupware, or collaborative software, a mismatch between the task done by users and the corresponding technology they are using could affect the co-operating people (Slagter, 2003), thus tailoring by end-users themselves is generally regarded as a suitable means to solve this problem. Due to a lack of a theoretical framework for tailorbility and the corresponding evaluation methods, results of different studies for groupware tailorbility are hard to compare. In our research, we mainly concentrate upon:

- Development of a collaborative architecture supporting tailorbility.
- Integration of technologies that has not been exploited before in the context of groupware tailorbility.

## 5.3 Research concerns

In our research work, we proposed the use of Web services with software agents' integration for the design of tailorable groupware, where the synergy of integration of those technologies has never been exploited in the context of tailorable groupware design. A first version of a groupware architecture that is based on Service-Oriented Architecture (SOA) has been proposed in (Cheaib, 2008).

On one hand, Web services have become one of the most important architectures for the cooperation of heterogeneous systems and have ushered in a new era of software design that focuses on implicit and explicit collaboration between organizations (Gannod, 2007). However, for (Maximilien, 2004), current techniques for publishing and finding services (such as WSDL and UDDI) rely on static descriptions of service interfaces, forcing consumers to find and bind services at design time. On the other hand, the concept of software agents is even older than web services, and it has been employed with success for executing distributed applications. The idea is our research work is to exploit software agents' proactive interaction capabilities in order to improve the behaviour of Web services in a service-oriented architecture, where system's components are based on Web services, with software agents having the essential purpose of searching available Web services on behalf of the users that best suit their needs, and integrate them seamlessly into the platform without affection the collaborative process, hence creating from Web services and software agents (that were originally developed using different standards and protocols) a cohesive entity that attempts to surpass the weaknesses of each technology, while reinforcing their individual advantages in the context of tailorable groupware design. Hence, the aim of this research work is to be applied on the sub-project *Oce@nyd* and hence offering an innovative approach to design groupware architecture, while bringing innovation to the CSCW (Computer Supported Cooperative Work) domain.

**5.3.1 Work in progress:** We began our research work by a state of the art on interactive and collaborative architectural models that are the most used and widely accepted in the community, such as Arch (Bass, 1992), Dewan (Dewan, 1998), Clover (Laurillau, 2002), etc., in the aim of building a global view of groupware architectures that are already existing in the literature. We found that all these models do mention tailorbility in their research work, and hence offering groupware architectures that are rigid, meaning that one cannot change the functionalities offered, and thus limiting users' choices with few functionalities already implemented in the system. This reinforces our motivation to deepen our work in the field of groupware tailorbility. Moreover, we have built a state of the art on the work done in the literature concerning the concept of tailorbility, as it has shown to be an essential property that should be taken in consideration in the design of collaborative systems, while it offers to users the possibility to adapt the application based on their needs and preferences, and not the other way around. Furthermore, a study has been done in the context of Web services and software agents' integration, while we propose to use some approaches in the literature to translate invocations between the two technologies, where they were initially designed using different standards. Hence, we attempt to bring existing technology without reinventing the wheel, while putting it in the context of tailorable groupware design.

## 5.4 Implementation concerns

At the implementation level, Ocea@nyd is a client/server application deployed on a Netbeans platform using JADE (Tilab, 2002) libraries, along with other libraries for implementing the Web services environment in the system, while the client/server communication is based on network streams. The mission of the software agents would be to manage Web services' search, invocation and integration into the platform based on non-functional attributes such as bandwidth, quality of service etc. with minimal user assistance.

In the first stage, we have implemented a Web interface that enables users to share their multimedia files by a drag/drop mechanism into a 2D bathymetric map provided by our partner SEMANTIC-TS. We can see a screenshot in Figure 7 below:



Figure 7: Screenshot of Ocea@nyd's Web interface

The interface offers functionalities as a chat mechanism where the users can exchange messages about the files shared, a video, audio and image viewer where they can search and visualize the multimedia files dropped into the map. Some Web services are implemented in the system such as a temperature converter and a weather forecast Web service.

**5.4.1 Scenario of use:** A typical scenario is shown in Figure 8, that starts with a user (we assume that a user is a professional diver or a diving club member that regularly does scuba diving) accessing his account in Ocea@nyd in order to collaboratively enrich, using a drag/drop mechanism, 2D plan biocenose maps of underwater sites provided by Semantic-TS. Upon connexion, the user will select from a list the underwater map that he/she wants to enrich with multimedia files (mostly images, video, audio and 3D objects). Before uploading the files, the user must fill out a form specifying the information concerning the files. More specifically, a user can specify the actual coordinates (specified by a GPS, or other underwater devices used by divers) of the location where the file is taken underwater, the time, temperature of the water, time etc. The user can also specify information about the site where the file was recorded, such as, water turbidity, god rays, luminosity, etc. When finished, the user can then upload his/her file on the server, and drag it on a specific location on the map where the file was actually taken in the real underwater site.

When dropped, the file is given an (x, y) coordinates (unless the coordinates are already specified by the user), depending on the scale of the map. Upon finishing the process of enriching the map, all information about the files dropped are saved, and an XML file is generated automatically that is put on the server in order to be edited by the administrator, Virtual Dive, while he/she can then check the files, delete irrelevant ones or modify others depending on their quality.

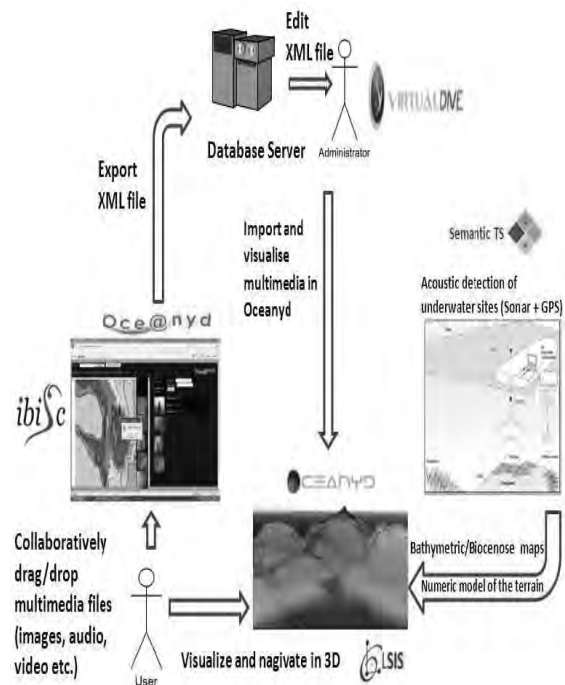


Figure 8 : Typical Scenario

The administrator then imports the XML file into the 3D Ocea@nyd application. The files are then put in their exact location, by the administrator, in the 3D environment that corresponds to the 2D map enriched by users online. When the process is over, the user will then be able to use the Ocea@nyd application in order to visualize and navigate into the 3D underwater sites. A game, Nautilus Quest, is already developed in order for users to play together on a mission for finding, for example, files or 3D objects that they had contributed for in order to enrich a specific underwater site.

Of course, update scenarios must be studied in order to generate the XML file of all new information between two particular laps of time, and not recharging all the information every time in the same XML file, thus taking in consideration storage limit, query processing and performance time for charging the data into their exact location in Ocea@nyd, using the coordinates for every information dropped into the Web interface of Ocea@nyd. The reason behind having two applications, one for the collect of information and the other for visualizing them, is that not all users have efficient bandwidth and internet speed in order to navigate online in 3D environments. Thus, dividing the process into, first, a collect of information using a 2D map, and then visualization on an offline 3D application constitutes a good solution to remedy this constraint.

In fact, the 2 applications Ocea@nyd and Ocea@nyd, complete each other, while each one of them has a separate aim and purpose; their combination represents a coherent system to create a complete and realistic view of the underwater environment with real data taken undersea. The link between the two applications (Ocea@nyd the online collaborative system, and Ocea@nyd, the offline 3D application) is mainly the information transmission generated by the former, and read by the latter as an XML file, in order to enrich and update the offline 3D environment with multimedia files collected by users online.

## 5.5 Discussion

The work done in the context of Océ@nyd brings technologies together such as Web services and software agents in the context of a collaborative platform that is specifically designed for groupware tailorability. This research is, until now, never been exploited in this context, hence bringing innovation in the CSCW (Computer Supported Cooperative Work) domain. In fact, the overall project requires an efficient mean to bind the different sub-projects constituting DIGITAL OCEAN. The use of Web services to enhance collaboration in the system is revealing to be very interesting after some tests we have done in our laboratory. Moreover, the use of software agents to enhance Web services behavior will reveal to be even more interesting as the aim is to dynamically integrate new functionalities into the platform with minimal human assistance. We are convinced that our system is highly innovative and brings existing technologies into a new domain that will enhance, eventually, people's interaction and communication in the digital world. We believe that our preliminary approach for groupware tailorability will continue to mature through the use of Web services and software agents, which revealed to be appropriate to bring this concept from theory to practice.

## 6. CONCLUSION AND PERSPECTIVES

In this paper, we introduced our on-going national project; DIGITAL OCEAN that is the system of distribution of multimedia content that results from the integration of three modules: Tryton, an underwater device for the dissemination of multimedia content, software for the edition of virtual environments, Océanyd, and a demonstration video game, Nautilus Quest. Virtualdive initiated Digital Ocean three years ago. The founders of the company invented the concept, developed and patented the submersible device *Tryton*, copyrighted the software *Océanyd* and the video game *Nautilus Quest*, where these modules constitute the project's main components. Furthermore, each partner of the project handles specific tasks that converge to constitute the project as a whole. In fact, the study of the commercial and financial viability of the project that validates its interest, is reviewed and updated during the prototyping phase, with the latest information about its capabilities, costs and the economic model that was ultimately upheld. Furthermore, the dissemination underwater device can be commercialized together or separately, offering more options on distribution. After study of the global market, there is no direct competition for the project, and the indirect competition doesn't constitute an obstacle.

Moreover, the project is in line with the current technology that is changing the entertainment industries, as well as tourism, education, sport and communication. It seeks to use the facilities offered by new technologies and multimedia to open to the general public, anywhere in the world, an infinite space, which so far it remained inaccessible, that is the underwater world, where the exploitation of undiscovered underwater sites might be very interesting for protecting eventual underwater heritage.

In fact, all scientific, technical and industrial knowledge is acquired to build the project are now mature enough to be deployed in order to build it, taking in consideration the deadline and budget that is set initially for it. We will continue our collaborative work between partners in order to build DIGITAL OCEAN that constitutes the first system to use new technologies in the underwater environment. Our project is totally innovative and has excellent perspectives on the global

market, where it opens to the multimedia and audiovisual industries a new space that is still virgin, that is the underwater space.

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# The Reconstruction of the Archaeological Landscape through Virtual Reality Applications: a Discussion about Methodology

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## ABSTRACT:

The Virtual Multiuser project Via Flaminia (a major consular road connecting Rome to Rimini, constructed in 220 B.C. by Gaius Flaminius) had for objective to create a “Virtual Museum of the via Flaminia”. The project started in 2005, focusing on the reconstruction of selected archaeological areas along the road (Malborghetto Arch - Tor di Quinto, Milvio Bridge, Grottarossa, Villa of Livia, Roman National Museum). The Virtual Reality (VR) application was recently installed (January 2008) in the Roman National Museum (Diocletian Thermal Baths) in Rome, which already displays objects coming from Via Flaminia.

The paper will describe the methodology used to implement the 3D architectural reconstruction based on real time navigation, and the technological issues related to this undertaking. Ancient sources were mined, architectonic comparative studies implemented to guide the reconstruction hypotheses. Indeed, the degraded remaining vestiges of the site do not provide sufficient information in their own to base the reconstruction work. On these grounds, a library of architectural elements and textures was created at three levels of resolution (simplifying the architecture’s geometry for the real time application and web) and served as starting point for construction of the 3D models. Particular attention was paid to the transparency of the approach and to the possibility for the viewer to confront the methodology and sources used. All hypothesis and data used in the virtual reconstruction are the accessible, ensuring the replicability and transparency of the reconstruction process, as a “scientific protocol”. A legend also explains the levels of reliability for each reconstructed element: low, medium and high. Furthermore, the application has strong interaction capabilities allowing for dynamic comparison functions..

## 1. INTRODUCTION

In this paper we will try to explain the methodology used for the reconstruction of the archaeological landscape passing through different phases of digital processing, from the fieldwork to the virtual reality, exploring the relations between data processing and data representation, between observed and reconstructed landscape. Core of this approach is virtual reality, a digital immersive system of interaction able to explore all the relations between spatial information: increasing factors of perception means to increase the knowledge of the landscape. In fact, a reconstruction process starts from the interaction of all the data from the beginning of the investigation until the final interpretation. Step by step virtual reality can take all the phases of processing and visualization (Forte 1995, 2000, 2000a) with the faculty to create maps of the environment in diachronic way, overlapping in 3D different sources of data.

The adopted approach for the landscape construction is the reconstruction of the environment and its multiple relations.

We may imagine the landscape as a fractal set: using a satellite sensor we can represent landscapes with a 30m to 20 cm resolution; on the field, a model resulting from laser scanner technologies reaches a resolution of less than 2 mm. Accuracy is thus a relative notion, leaving the option for the modeler to choose the best resolution on the basis of tradeoffs between amount of information, representation and communication.

In computer graphics, accounting for level of detail involves decreasing the complexity of a 3D object representation as it moves away from the viewer or according other metrics such as

object importance, eye-space speed or position. Level of detail techniques increases the efficiency of rendering by decreasing the workload on graphics pipeline stages, usually vertex transformations. The reduced visual quality of the model is often unnoticed because of the small effect on object appearance when distant or moving fast.

Although most of the time L.O.D is applied to geometry detail only, the basic concept can be generalized. Recently, L.O.D techniques included also shader management to keep control of pixel complexity.

## 2. AN INTEGRATED APPROACH: THE DIGITAL PROTOCOL

What we intend for digital protocol is a sequence of methodological steps integrating different technologies and multiple data in order to create a virtual reality system able to show all the spatial relations and connections of the landscape in micro and macro scale and in real time. Each phase of the work is marked by a virtual set of 3D interactive data available in a virtual reality system.

The reconstruction of the archaeological landscape should not be limited to the representation of an empty and silent space: space has to become “place”. The main aim of virtual reality is the creation of a digital virtual ecosystem to integrate geographical, archaeological, perceptive, interpretative, narrative and symbolic data.

All the contents and metadata have to be connected to 3D models, as “affordances”, cultural relations that the contexts and its elements can develop [Gib79]. Every objects, structure, place have relations of contents, such as Space, Time, Use, Type, Similarity. If the user has the possibility to interact with the model, de-constructing and reconstructing it according to different kinds of relations, he will be able to compose his own cybernetic map and learning will be greatly improved.

A key aspect is the multiplication of levels of detail, from an holistic to a monographic vision, in order to extract different scales of detail from territory. Every level of representation is able to give us different kinds of information about the context in terms of topographical and cultural relations. The bottom - up approach (acquiring data on the field and elaborating models from what is still visible today) needs to be integrated by the top down process: the critical study of bibliographic references, typological comparisons with similar and historical buildings, iconographic sources, analysis of fragments, and so on [VMV06]. In this way we can be able to interpretate functions, aspects, uses, habitual visiting of structures and places and propose a reconstruction, more or less reliable but always supported by a scientific approach.



Figure 1: Flaminia project (CNR-ITABC):  
Roman Villa of Livia, Rome.

### 3. TECHNIQUES AND METHODS

The Vhlab is working on different projects using methodological conclusions for the creation of virtual reality systems based on models of high accuracy and detail. Our discussion about methodology will sometimes refer to the study-cases of Via Flaminia Antica, Via Appia and Virtual Rome in order to explain clearly some general concepts and our approach on virtual reality and cultural heritage.

The Virtual Rome project consists in the development of a open source webGIS 3d (or VR webGIS) reconstruction of Rome’s archaeological landscape, (in particular about the North area with Via Flaminia; the South area with Via Appia and the Center with Imperial fora). The aim of Virtual Rome project (that is still undergoing) is to implement a system of web-based open source libraries (OpenSceneGraph) to be used for the reconstruction of roman diachronic landscape, integrating this

three areas of relatively high resolution through the modeling of current landscape, the proposed reconstructed landscape and some ancient and archaeological sites and the development of multimedia content (movies, schedules). All modules are optimized for web use. The web system provides for the development of some skins such as personal navigation flight, the switch between different landscapes in the time (current / Roman-imperial time), the activation of viewpoints and content. The aim of the Via Flaminia project is the construction of a digital environment, oriented towards a real time application, that individualizes two levels of perception.



Figure 2: Flaminia project: Villa of Livia,  
VR application related to 3D models.

In the first one we have an holistic vision of the entire road from Rome to Rimini, based on maps, archeological and technical cartography, aerial and satellite photos, GIS data. In the second one, we can have a micro-space vision that focuses the attention on five sites. This local entities are Grottarossa, Ponte Milvio, Malborghetto-Tor di Quinto, Villa of Livia and the Virtual Museum (sanctuary of Anna Perenna; praetorians necropolis of Ponte Milvio).

For every site we have chosen the most appropriate techniques according to its topography and the kind of information we wanted to extract. For example the site of Malborghetto (XIII mile of *Via Flaminia*) has been reconstructed through photomodelling techniques; this method is used to obtain 3D spatial model with low number of polygons. For more complex cases, like Livia’s Villa at Prima Porta (IX mile of *Via Flaminia*), every single structure has been acquired using laser scanner technology.



Figure 3: Current state of Livia's villa

The aim is to reach, in every single case, a suitable compromise between the level of detail and the need to manage models in real time.

The successive phase is the placement of every measured model in the correct topography of the holistic context. 3D models of the monuments have been inserted both in the reconstruction of the actual territory and of the ancient roman landscape one.

The positioning of the 3D models has been possible through their integration with GPS and total laser station surveys.

The reconstruction of the archaeological landscape involves not only architectonic elements, but also the general ecosystem in which they are. We have created graphic libraries of animals, plants actually observable in the landscape or referred to the ancient contexts, for which paleo-environmental studies have been necessary. These graphic libraries, iconographies, studies helpful for the landscape reconstruction and design, together with the graphic library of the roman architectonic elements elaborated in the progress of our projects, represent a very useful collection of repertories that we will be able to use for next future applications.

The case of Livia's Villa (the suburban villa of Augusto's wife) was very problematic: the complexity of the architectonic system, the insufficient and partial credibility of the planimetry in public archives and the scant information caused by incomplete excavations, have convinced us to begin a very detailed topographic survey through laser scanner, in order to obtain 3d models with a resolution of 6mm. This technology represents an enormous potential of publishable, up-to-date, available and, above all, georeferenceable information, fundamental for an archaeological contextualized knowledge of the territory and in a position to transmit a strong evocative and communicative component.

From 3D registered point clouds we have generated high resolution mesh models, described by interpolated faces and textured with orthophotos. Models are perfectly measurable and no gap is between data acquisition, knowledge and communication.



Figure 4: Flaminia project: Villa of Livia. Rooms modelled with RapidForm and textured with 3ds Max

Laser scanner acquisition has involved both the architectonic compound of Livia's Villa and the surrounding perimetral areas of the hill on which it exists, in order to create a coherent and precise topographical constraint between the architectures and the terrain. After the high resolved mesh models have been obtained in Meshlab or RapidForm, decimation is needed in order to manage models in real time. Once imported a model in 3d Studio Max, we use the MultiRes modifier, which reduces the memory overhead needed to render models by decreasing the number of vertices and polygons.

MultiRes offers several advantages, including the ability to specify reduction as an exact percentage or vertex count.

Now, the only real problem seems to be the file size. In order to allow Multires to work well, the only solution is to divide the model in more parts with the consequence that, after decimation, we are often obliged to sew together the edges of the divided objects, vertex by vertex.

In the case of Malborghetto (an ancient roman arch and now, after many transformations from medieval age to nowadays, a museum dedicated to some archaeological sites along *via Flaminia*) we are in presence of a monument with a very regular geometry. Moreover there are no relevant obstacles to an all-around photographic relief, so the choice was to employ the photomodelling technique. Photomodelling is a photogrammetric technique that extracts measurements and 3D models from photographs. The acquired pictures are imported into a specific software (Photomodeller for instance) in which it is possible to correct the perspective distortion of the lens of the camera through specific functions of calibration. Photomodeler combines the photographs and locates the marked features in three dimensions. The final result is a 3D model textured, scaled and spatially correct, that can be transferred to any 3d modelling or CAD software.

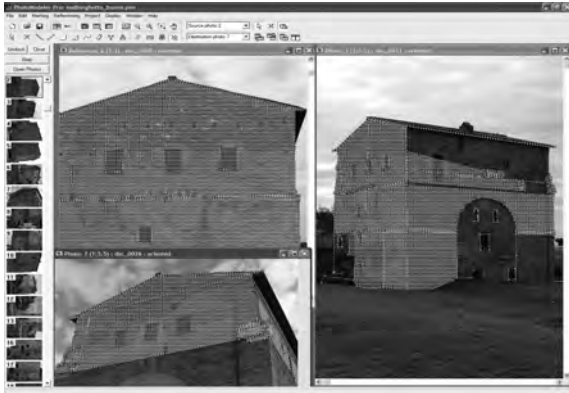


Figure 5: Malborghetto: the photomodelling tecnique

From the last three years we have been experimenting also Computer vision technique, an innovative method developed by the KU Leuven, ( Epoch European project). Computer vision allows to construct 3D models from a set of digital photos taken from different camera positions all around an object, (following not circular but linear paths for each side). Photos are sent to a server where a specific software, based on a pixel-recognition algorithm, orientates the photos in the 3D space. This is possible because software defines automatically some control points through which photos are oriented. After this process, the server sends again oriented photos to client. A client-player generates the 3D model, based on couple of oriented images. Models obtained from each couple have the same spatial coordinates and they will be automatically aligned in a 3D modelling software, such as Mesh lab developed by CNR-ISTI of Pisa. The advantages of this technique are the low cost of the operator equipment, just a digital camera, and the final result, a 3d texturized model.

The limits are the scant precision of the mesh and a quite high level of point cloud noise, with the consequence of obtaining a mesh lacking of detail, too smoothed and flattened. The only way to keep the low noise is to improve the median size level up to 20-25. Improving the median size also dramatically increases the polygon count, and the file size, causing many crashes when we try to import the mesh in the 3d modelling software. Using the VRML as exporting file format we obtain an unwelded vertices mesh, so before using the MultiRes modifier we have to convert the mesh to an Editable Poly, select all the vertices and weld, setting the Weld Threshold on 0,001m. Welding the vertices together also enables the use of the relax modifier, in order to reduce the noise level of the surface.

All the three-dimensional models, elaborated from different kinds of data (laser scanner, photomodelling, computer vision, photogrammetry, GIS) and in different softwares, are further imported and optimized in 3D Studio Max. Here we improve the quality of the landscape designed and of the final rendering (setting lights, applying, normal maps, UVWrap, render to textures, modelling vegetation, animals, characters and creating animations).

From 3D Studio Max, models and scenes are exported for real time graphic engine where behaviours, metadata, tools of

interaction are implemented and integrated. We have developed our off line VR project in Virtools DEV, and now we are working with OpenSceneGraph.

### 3.1. Modelling for real time and on line applications

The methodology for the virtual reconstruction is common but the post processing differs depending on the use of data (on-and off-line application). On-line (web) requires in our case three levels of detail, therefore three different models in geometry and texture (very simplified, simplified and details). We have developed different optimization approaches, according to the local or web based modality, even if we have used the same 3d models (the original survey of the monuments is the same). Decisions on the export file type, weight and polygons number, size of textures and so on must thus be made according to the final destination of the modelling. The methodology for the landscape and architecture reconstruction is unique, but differs in technical aspects, depending on different levels of perception.

The preparation of a real time model requires a raw and bulky models to be optimised, and especially to reduce the number of polygons and ease the texture management. Two approaches were tested in this respect drastically reduced polygon number and textures size, because the bitrate in most cases is very low, and we should wait a very long time to visualize the complete model.



Figure 6: Current state of Forum of Augustus.  
Imperial Fora, Rome.

The first one consist in a 3d Studio Max modifier, MultiRes, which reduces the memory overhead needed to render models by decreasing the number of vertices and polygons. This modifier allows the reduction of the exact percentage or vertex count. The initial model detail consents to generate an accurate decimated model.

The second optimization technique is another modifier of 3d Studio Max, the Normal Mapping. This approach permit to fit to a low poly model the same accuracy and detail of a high poly ones. We have testing this method that ensures the best compromise between graphic quality, number of working hours and the need to manage models in a VR on-line real time systems. One of the most interesting uses of this technique is to

greatly enhance the appearance of a low poly model exploiting a normal map coming from a high resolution model. Three models of the same monument has been produced, low, middle and high polygon model, the most detailed one (fig. 7).

The low model is a little bit more detailed than a bounding box, having the same global dimensions (height, depth and width) of the whole monument; the final texture for each face of this model will be the rendering of the corresponding faces most detailed model. The low model will be the first to be visible, when the camera is very far (more than 1.000 meters for example) the model resolution in this phase must as low as possible, because the viewport is already full of terrain and vegetation geometry, and the application could slow down too much. When the camera moves closer to the monument, the visible terrain and vegetation geometry decreases, so we can increase the monument geometry switching into the mid model, going on with the camera we can see the model at full resolution. Regarding the columns, they have a peculiar processing: each column has a dedicated L.O.D., so when the camera is moving through the colonnade the columns nearest to the point of view are at full resolution, while the most distant have a low level of detail. In fact, loading the whole hi-resolution scene with all the columns at full resolution the polygon count grows up to 343.090. Another technique was used to visualize the very detailed decorations of roman monuments facades: the bump shaders. Used to Reduce the polygon number of 3D objects without removing details. The pipeline to produce this shaders is quite complex: (fig. 8)

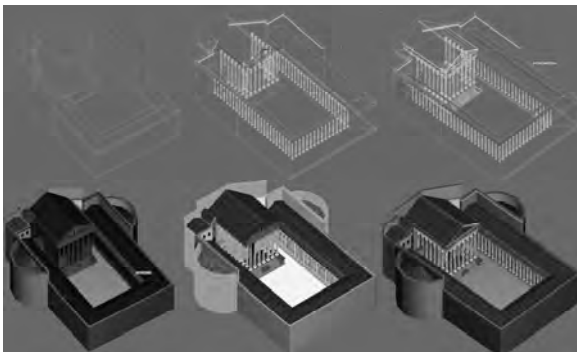


Figure 7: low, mid and hi polygon models of Forum of Augustus: 174; 11.411 and 17.928 polygons respectively (columns not included)

Once obtained the final image, to produce the right effect using the displacement maps, we reduced the light/shadow contrast to avoid wrong bump result on the hi-res surface. We used previously the displacement maps over a millions-polygon projection-surface, then a normal bump map was baked on a plane made with only two triangles. The result is a very low poly surface with a baked normal bump map, storing all the detail of the hi-res surface, wich gives the illusion of a very detailed facade reproduction.

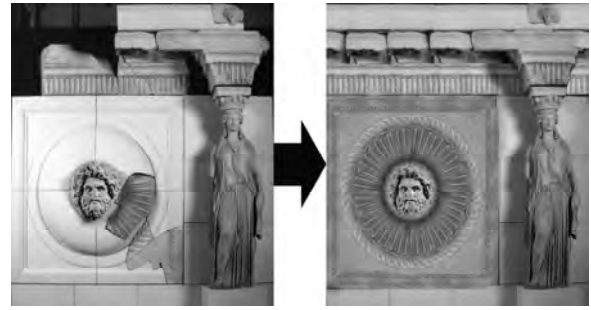


Figure 8: normal bump map: plane 1: 2.000.000 polygons, plane 2: only two polygons.

#### 4. THE RECONSTRUCTIVE PROCESS

Reconstructive research in the field of the virtual archaeology uses top-down and bottom-up rules (Forte 2000) in interpretative processes, integrating multiple methodologies. The bottom-up pattern starts from modelling data captured on the field, from the spatial connections represented from the extrusion of plans and front elevation, for creating, finally, a virtual “anastylosis” of the archaeological structures (connecting all points and traces on the ground and reproducing shapes of any kind of man made products) On the other side, top-down rules use the mental faculty of making reference patterns (we could call mental maps) for interpreting and reconstructing the past. Showing 3D relations through interactive and inclusive activities means to develop new rules of perception; that is the virtual environment becomes a place of knowledge established by and with relations. “The ideal VR system is conceived here as an ecology, in which every object is a tool that extends the user’s body and enables her to participate in the ongoing creation of the virtual world” (Ryan 2001). The reconstructive process of a virtual model can be synthesized in:

- the Virtual of the Existing (documentation)
- the Virtual of the Hypothetic (representation)
- the Dynamic Virtual (communication).

The Virtual of what is existing is referred to high resolution digital reproduction of the heritage, therefore it becomes a primary model of knowledge; it can be considered an artificial transposition of artefacts, sites, landscapes, monuments, collections, after the reproduction on scale of the model.

The hypothetic or imagined virtual corresponds to what is hypothetically reconstructed on the basis of the existing documentation of remaining structures (excavations, ruins, settlement traces, etc.) or through comparative analyses.

The “dynamic virtual” uses the results of self-learning and feedback within the virtual space for enhancing unknown relations within the environment.

The study of materials supplies another important aspect: we may learn of its mechanical abilities which condition architectonic aspects such as the height of walls, cover systems, etc. A completed digital 3D processing of acquisition and representation will be the best basis of knowledge according to an integrated approach in order to minimize the risk to lose scientific data (Forte, 2003). Once they are developed, digital



models can provide substantial support. The recording and communication of the images through the digital archives has become a strategic instrument for the numerous activities which it can supervise. For the photographic agencies it is the instrument of main job, for the industry and scientific culture it is an excellent and modern vehicle of communication. At the technical level of virtual heritage, they consolidate numerous disperse information and therefore facilitate any decision making prior to intervention. They facilitate the diagnosis of different structures and constructive techniques of the past. They complete and complement the graphic existent documentation with plotting of ruins and vestiges. At the historic level, the models allow to represent the building through the ages, following the succession of interventions. Finally, from a methodological point of view, models offer elements of analysis for the study, and preservation of the architectonic patrimony.

Scientific digital modelling of Cultural Heritage favours a conceptual surrounding defined by the perceptive restoration of architectonic space. Digital models are also instruments for suggestive and accurate representation of reality or hypothesis that do not require interventions that could prove to be costly and irreversible. They also have the interest of being opened and interactive processes. The user can access the model as many times as necessary to generate new images or to modify and improve the design as soon as new information is made available or new hypothesis proposed. Once the virtual reconstruction is finished, all generated information becomes part of the documentation regarding the building. The model output is a synthetic, accessible and suggestive document that contributes to progress in analysing the building and, beyond, in art history.

The analysis of the state of the places allows us to draw conclusions about possible logical 3D reconstructions, tied to the constructive rules and ours cultural background. In classical architecture, the relationship of interdependence between plant and prospect has one independent logical. They serve in order to organize the space, and often in the archaeological diggings, we find only partial horizontal section and nothing of the prospects. The original architecture morphology can be understood through the typological and material analysis. The structural verification, through the calculation of graphical static, represents a fundamental instrument in order to ratify the reconstructive hypotheses. Roman architecture is based on geometric elementary shapes like the regular circle, polygons and rectangles. The Arithmetic determines the shapes and the dimensions of the space and the architectonic elements with measurable proportions, like the proportion 1:1, 2:1 (both geometric and Arithmetic), 2:3, 5:4,  $\sqrt{2}$ ,  $\sqrt{3}$  etc. This approach is valid not only for the structure but also for the decorations. The study of materials supplies another important aspect. The mechanical abilities of the materials condition architectonic aspects like height of walls, systems of cover, etc. The design is a process, a dynamics interaction between concept and contingency, generic and specific that evolves progressively in a variety of decisions that come assimilated "into the whole" (Vassallo, Moro Vico, From Space to place, 2006).



Fig. 9: Current state and virtual reconstruction of the Nynphaeum of Egeria

## 5. CONCLUSIONS

A key issue in archaeological research is the reconstruction of the past throughout highly destructive activities, such as excavations, and non-destructive landscape investigations like topographic surveys, remote sensing applications and digital technologies. All these activities, intra-site and inter-sites, create a huge amount of information of difficult accessibility because of different archives, platforms, acquisition methods, standards, type of data, etc.

Because of the very long process to elaborate this set of information, unfortunately, most part of the archaeological investigations are unpublished and, if published, the dissemination is, more or less, limited to the scientific community, with a minimum social impact and few perspectives of didactic communication. In addition, in many cases the VR applications are not integrated in the process of reconstruction of the archaeological landscape, and they represent a separated domain.

It is important to consider a 3D environment not as a definitive and intangible result, but as work in progress following preliminary and partial hypotheses, open to all the users. The growing use of digital technologies for the classification, interpretation and reconstruction of the archaeological landscape needs an integrated approach and a cross-platform for an advanced level of scientific communication and didactic understanding.

The hyper specialization of the methodologies of research in separated fields compromises a holistic vision of the entire frame of data and information. In contrast, visualization, interaction and accessibility of data, models and images within a 3D spatial virtual environment amplifies our perception and the communicational level of the information set.

The process of virtual reconstruction is documented only in the archaeologist's mind and it is not transparent or accessible after the final interpretation. So, doubts, hypotheses, predictive models, comparisons with different models, do not appear in a final scientific report, and the fundamental phase of dialectic

interaction with the archaeological information is thus lost. The progressive understanding of the past is also missed. In contrast, the process of learning and cultural transmission is a cybernetic difference between us and the environment we explore: we learn through the difference. In fact, the construction of a spatial virtual reality system dedicated to the investigation of the ancient and archaeological landscape, can constitute the beginning of a new challenge for the archaeological methodology, passing directly from the fieldwork to the virtual reality, from the scientific domain to a collective communication, keeping all the data within the same interactive environment. This result can be obtained on the basis of a technological integrated approach collecting all the data in a VR system: GIS, remote sensed and spatial data, monuments, structures, mental maps, everything reconstructed and surveyed in 3D.

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## DETAILED 3D RECONSTRUCTION OF THE GREAT INSCRIPTION OF GORTYNA, CRETE: ACQUISITION, REGISTRATION AND VISUALIZATION OF MULTI-RESOLUTION DATA

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**KEY WORDS:** 3D modeling, multi-resolution, integration, image matching, laser scanning

### ABSTRACT:

The article reports the interdisciplinary project of the virtualization of the Great Inscription of Gortyna (Crete) for documentation, structural studies and physical replica purposes. The digitization of the inscription (6 m long and 1.75 m high, with ca 3 mm depth engraved letters) and its surrounding heritage area, required a long planning and the construction of a dedicated acquisition system (mobile motorized structure with a triangulation-based scanner) to speed up the surveying time, limited to few hours per day. For research purposes, a small part of the inscription was also modeled using advance image matching algorithms. The 3D digitization (and physical replica) of the heritage is now the basis for further archaeological studies on the incision techniques and a deeper structural analysis of the evidence of “suffering” of the monument. The challenges of the work stay in the acquisition, processing and integration of the multi-resolution data as well as their visualization.

### 1. INTRODUCTION

The actual technologies and methodologies for Cultural Heritage sites or objects documentation and modeling allow to obtain very realistic 3D results (in terms of geometry and texture) which are then used for digital conservation, restoration purposes, VR/CG applications, 3D repositories and catalogs, web geographic systems (e.g. Google Earth, Microsoft Virtual Earth). According to some parameters (mainly budget, size, material, location) and the modeling experience, active or passive sensors are employed or an integration of them, trying to exploit the intrinsic potentialities of each technique.

The systematic and well-judged use of 3D models in the Cultural Heritage field started just recently but it is still applied in not many case studies and not yet employed as a default approach for different reasons: (i) the high cost of 3D; (ii) the difficulties in achieving good 3D models by everyone; (iii) the consideration that it is an optional process of interpretation (an additional “aesthetic” factor) and documentation (2D is enough); (iv) the difficulty to integrate 3D worlds with other 2D material. But the availability and use of 3D computer models of heritages opens a wide spectrum of further applications and permits new analyses, studies and interpretations. Thus virtual heritages should be more and more frequently used due to the great advantages that the digital technologies are giving to the heritage world.

The article reports the interdisciplinary project of the virtualization of the entire heritage area of Gortyna (Crete) with its Great Inscription (Figure 1) for documentation, structural studies and physical replica purposes. The digitization of the wall (ca 8 m long and 3 m high) containing the Great Inscription (with 3 mm depth engraved letters) needed a long planning, the construction of a motorized scanning acquisition system and large editing time to process the huge amount of data. For research purposes, a small part of the inscription was also modeled using advance image matching algorithms, to demonstrate the potentialities of our newly developed image-based surface measurement procedure and to show that between range- and image-based approaches there are no more differences in terms of accuracy and retrievable details.

#### 1.1 Brief historical background

The Great Inscription, ca 6 m long and 1.75 m high, dates back to the middle/late 5<sup>th</sup> century BC and was discovered inside a watercourse in the beginning of last century by Federico Halbherr. Halbherr was an Italian epigraphist and archaeologist who devoted his life to discover Cretan antiquities. His major works are the excavations carried out in the Idaion Antron, at the Minoan palace of Phaestòs, at the Minoan “villa” of Haghia Triada, at the city of Gortyna. Halbherr arrived in Crete for the first time in June 1884, following a suggestion of his teacher, Domenico Comparetti, and after just one month he made the discovery of the inscription. Halbherr found some stone blocks



Figure 1: The Odeion area and the vaulted brick roof (A) which covers the Great Inscription (B) of Gortyna, Crete, 5<sup>th</sup> century B.C. Detail of the image-based (C) and range-based (D) reconstructed 3D model of the inscription with its 3 mm depth letters.

with incised letters of the Greek alphabet and with many difficulties he brought to light all the blocks which formed a single monument. The inscription is written in Doric dialect, read boustrophedon and it is part of a law code of the Cretan city of Gortyna, the capital of the Roman province of Crete (near the actual village of Haghii Deká). The inscription, with 0.3 cm depth (in the best case) engraved letters, is an integrated series of provisions covering a wide range of related subjects, which together constitute the written law of the community (Whitley, 2005). The inscription is also called “The Queen of Inscriptions” (Willets, 1967) and is the longest epigraphic text of the Greek civilization. The original setting of the Great Inscription is uncertain, but in the Roman period the incised blocks were reused as a part of an Odeion (a building intended for musical performances). After the discovery, the inscribed wall was covered with a vaulted brick roof originally aiming to protect it but nowadays causing damages to the inscription itself. The importance of the Great Inscription is multiple, as a source for knowledge of ancient Cretan institutions and Doric dialect, as a monument and as a legal text.

## 2. REALITY-BASED 3D MODELING PROCEDURE

Nowadays, 3D modeling of objects and sites is generally performed by means of images or active sensors (like laser scanner or structured light projectors), depending on the surface characteristics, required accuracy, object dimensions and location, project’s budget, etc. Active sensors (Blais, 2004) provide directly 3D range data and can capture relatively accurate geometric details, although still costly, usually bulky, not easy to use, requiring stable platform and affected by surface properties. These sensors have limited flexibility, since a range sensor is intended for a specific range/volume and generally lack of good texture information. They can acquire millions of points, even on perfectly flat surfaces, often resulting in over-sampling, but it is likely that corners and edges are not well captured. The range-based modeling pipeline (Bernardini and Rushmeier, 2002) is

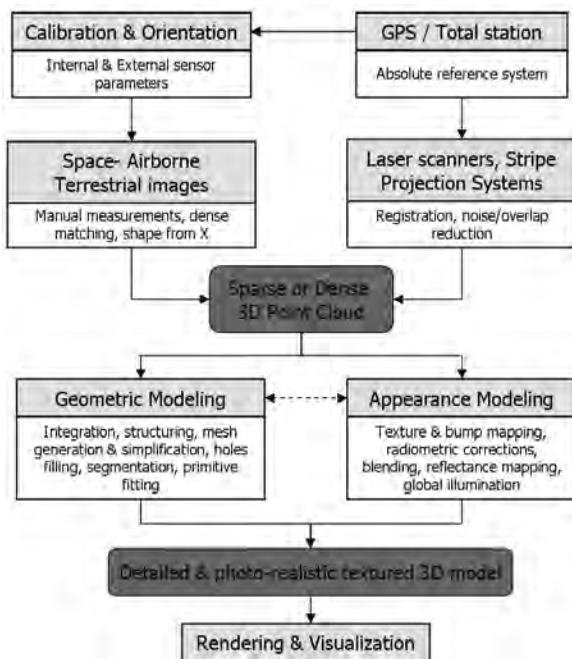


Figure 2. 3D modeling pipeline for Cultural Heritage object and site documentation.

nowadays quite straightforward but problems generally arise in case of huge data sets.

On the other hand, image-based methods (Remondino and El-Hakim, 2006) require a mathematical formulation (perspective or projective geometry) to transform two-dimensional image observation into 3D information. Images contain all the useful information to derive 3D geometry and texture but the recovering of a complete, detailed, accurate and realistic 3D textured model from images is still a difficult task, in particular for large and complex sites and if uncalibrated or widely separated images are used.

Although many methodologies and sensors are available, nowadays to achieve an accurate and realistic 3D model, containing all the required levels of detail, the better way is still the combination of different modeling techniques (Figure 2). In fact, as a single technique is not yet able to give satisfactory results in all situations, concerning high geometric accuracy, portability, automation, photo-realism and low costs as well as flexibility and efficiency, image and range data are generally combined to fully exploit the intrinsic potentialities of each approach (Stumpf et al., 2003; El-Hakim et al., 2007).

## 3. THE PROJECT

For the digital 3D documentation of the Great Inscription of Gortyna and its surrounding area, range sensors were used. Although aware of the potentialities of the image-based approach and its developments in automated and dense image matching (Brown et al., 2003; Goesele et al., 2007; Remondino et al., 2008), the reliability of active sensors and related range-based modeling software in certain projects is still much higher, although time consuming and expensive. Therefore, mainly for research purposes, only a small part of the wall was imaged with a SRL digital camera and the image matching 3D results were afterwards compared with the range data.

In our project, similar to other image-based (Gruen et al., 2005), range-based (Bonora et al., 2005) or mixed (El-Hakim et al., 2005) approaches, various sensors, used at different geometric resolution, were integrated to produce a multi-resolution 3D model of the entire heritage area of Gortyna. Our approach is hierarchical by the data source and in the hierarchy, details and accuracy increase as we get closer to the Great Inscription. Thus data in one level overrides and replaces the overlapped data found in previous levels of resolution.

In the following sections, we summarise the acquisition, processing and texturing of the range data as implemented for our multi-resolution project. A final section reports the image-based modeling of a part of the inscription.

### 3.1 Range-based modeling

#### 3.1.1 Range data acquisition

Due to the project requirements and the need of a physical replica, the data acquisition was divided in different parts (inscription, wall, protection, surrounding area), with different parameters and specifications. Following Beraldin et al. (2007), the scanning results are a function of:

- intrinsic characteristics of the instrument (calibration, measurement principle, etc.);

- characteristics of the scanned material in terms of reflection, light diffusion and absorption (amplitude response);
- characteristics of the working environment;
- coherence of the backscattered light (phase randomization);
- dependence from the chromatic content of the scanned material (frequency response).

All the range sensors, in particular the triangulation-based systems which aim at very high-resolution and accurate scans, should be calibrated before use. Furthermore, to verify the achieved calibration parameters, certified and NIST-traceable objects (e.g. balls bars, gauge blocks, etc) should be used.

All these factors and precautions were taken under consideration in the project planning and instrument's selection.

As the inscription contains carved symbols and letters with a depth of 2-3 mm (Figure 3), it was digitized with a ShapeGrabber® laser scanner at 0.3 mm resolution. The triangulation-based scanner, equipped with a SG1002 head, is mounted on a mechanical linear rail system (PLM600) which allows a 60 cm horizontal translation of the sensor. The minimum acquisition distance (standoff) is 300 mm and the Depth of Field (DOF) is 900 mm. The range camera is capable to acquire  $n=1280$  points for each vertical profile. The angle  $\varphi$  covered by the laser line is ca  $42^\circ$  and the resolution along the horizontal  $x$  axis is directly related to the camera-to-object distance  $d$ :  $\Delta x \cong d \cdot \frac{\varphi}{n} \cdot \frac{\pi}{180^\circ}$ . According to the project

requirements, the camera-to-object distance was set to 500 mm to achieve a resolution of 0.3 mm. Due to the strict project requirements, the scanner was precisely calibrated before each acquisition session. Furthermore, to speed up the acquisition of the entire wall, a mobile motorized structure was built (Figure 3) to quickly move vertically and on the ground the instrument.

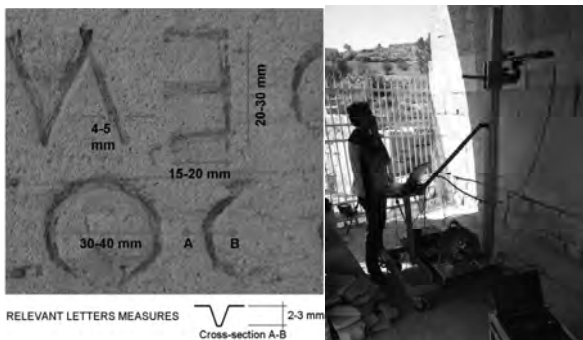


Figure 3: Relevant letters measures on the Great Inscription (left). The range sensor mounted on the mobile motorized structure carrying the scanner (right).

For the interior and exterior vaulted brick protection (ca 8 x 5 x 4 m) as well as for the surrounding heritage area (ca 30 x 30 m), we employed a Leica ScanStation2 Time of Flight (ToF) laser scanner, at different spatial resolution (Table 1). Those data were mainly used to contextualize the entire inscription and for visualization purposes.

### 3.1.2 Range data processing

In the data processing of large sites, we should consider that:

- the huge amount of range data makes almost impossible their processing at high resolution, yet processing at low resolution creates accuracy problems;
- the combination of data acquired with different sensors or at different resolution, accuracy and viewpoints can affect the overall accuracy of the entire 3D model if not properly considered;
- despite combining several sensors, some gaps and holes can still be present in the model, requiring filled and interpolated surface patches (but possibly inaccurate) not to leave them visible and unpleasant;
- the used sampled distance is rarely optimal for the entire site or object, producing under-sampled regions where edges and high curvature surfaces are present and over-sampled regions where flat areas are.

Generally the first operations on the acquired range data are errors and outliers removal, noise reduction and holes filling (Weyrich et al. 2004) while afterwards the aligning (or registration) of multiple scans is performed. After a raw alignment, a more precise and robust registration technique like ICP (Salvi et al., 2007) or LS3D (Gruen and Akca, 2005) is applied. Once the scans are aligned, they are generally decimated to remove redundant points and then converted to a mesh, the typical standard for surface reconstruction from range data. For these reasons and also for fastest processing, other methods (point-based techniques) were developed (Kobbelt and Botsch, 2004). If a mesh is generated, its triangular elements generally need some repairing to close holes, fix incorrect faces or non-manifolds. Those errors are visually unpleasant and might cause lighting blemishes due to the incorrect normals and the computer model will also be unsuitable for reverse engineering or replicas. Finally over-sampled areas should be simplified while under-sampled regions should be subdivided (Dey et al. 2001). The available commercial packages (e.g. Polyworks, Geomagic, RapidForm, Reconstructor) are based on long years of experience and they include a variety of optimizations and functionalities although some inherent problems are still present, in particular for the handling and visualization of large meshes. Some research packages are also available to handle range data (e.g. MeshLab, VripPack).

In our project, as soon as a vertical scanning stripe was completed and before the motorized structure was located in the successive location, the range data were registered with Polyworks® to check the complete coverage of the inscription.

After the scanning of all the stripes, all the 212 patches (ca 460 million points) were globally aligned achieving a final standard deviation of 0.27 mm, in agreement with the sensor's specifications. This procedure required to set up a cluster of two 64 bits PCs with 8 Gigabyte of RAM each. The final 3D surface model of the entire inscription at 0.3 mm resolution was afterwards decimated and sub-sampled (0.5 mm and 1 mm) for further texturing and visualization purposes (see Section 4.2).

For the surrounding area (wall, protection of the Great Inscription and Odeion) the range data acquired with the ToF scanner (Table 1) were processed and registered following the same strategy previously described and used for the visualization of the entire heritage area of Gortyna. The wall, acquired at 5 mm resolution, was used to check the correctness of the aligned ShapeGrabber data.

### 3.1.3 Range data texturing

The generation of a photo-realistic result essentially requires that there is no difference between a view rendered from the model and a photograph taken from the same viewpoint. The texture mapping phase goes much further than simply projecting one or more static images over the 3D geometry. Problems rise firstly from the time-consuming image-to-geometry registration and then come because of variations in lighting, surface specularly and camera settings. Generally the images are exposed with the illumination at imaging time but it may need to be replaced by illumination consistent with the rendering point of view and the reflectance properties (BRDF) of the object (Lensch et al., 2003). High dynamic range (HDR) images might also be acquired to recover all scene details (Reinhard et al., 2005).

Area	Sensor	Dim [m]	Scans	Acquired pts [Mil]	Reduced pts [Mil]	Mesh resolution [mm]	Final numb polygons [Mil]
Inscription	ShapeGrabber SG1002	6 x 1.75	212	460	375	0.3	80
					176	0.5	65
					85	1	38
Wall	Leica ScanStation2	8 x 3	3	1.2	0.9	5	1.6
Protection (int+ext)		8 x 5 x 4	14	4.8	3.1	10	1.4
Odeion		30 x 30	15	55	31	50	3.1

Table 1: Summary of the acquired multi-resolution range data and the derived surface model characteristics.

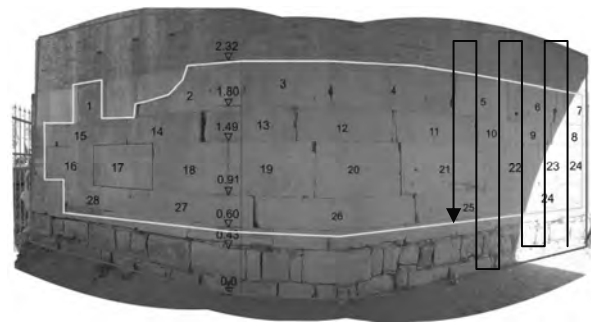
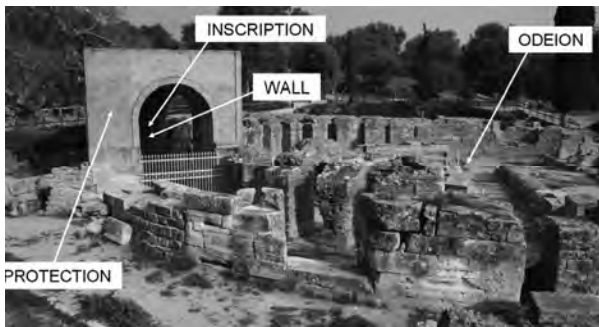


Figure 4: The entire heritage area of Gortyna with the Odeion and the protection of the wall which contains the Great Inscription (left image). The entire wall inside the vaulted brick protection (red contour) and the inscription (yellow contour), constituted by 30 engraved stones and digitized along 12 vertical stripes, highlighted in black (right image).

rate than computer hardware advances and this limits the possibilities for interactive and real-time visualization of the 3D results. For large 3D models, simplification, LOD and multi-resolution approaches are generally used to display huge data sets and maintain seamless continuity between adjacent frames (Pajarola and DeCoro, 2004; Cignoni et al., 2005; Borgeat et al., 2007). Nevertheless data simplification arises the problem of a loss of geometric accuracy of the generated 3D model and this poses the crucial question: shall we really spend hours and hours of scanning to collect millions of points to accurately describe the smallest element and then simplify and reduce all this information because then we cannot visualize it?

### 3.2 Image-based modeling

For research purposes, two small areas of the detailed inscription were imaged with a 12 Mpixel SRL Kodak DCS Pro digital camera equipped with 35 and 50 mm lens previously calibrated in our lab. The footprint of the images was 0.09 and 0.15 mm. After a bundle adjustment for the image orientation (sigma naught 0.4 pixel), we employed a multi-photo geometrically constrained image matching

We textured the Great Inscription model and the surrounding areas using TexCapture and Kodak DSC-Pro digital images at 12 Mpixel (18 mm and 50 mm objectives).

### 3.1.4 3D data visualization

After the generation of a static photo-realistic 3D model, the results should be visualized (possibly in real-time and at full resolution) for communication, entertainment, advertisement, etc. The ability to easily interact with a huge 3D model is a continuing and increasing problem. Indeed model sizes and resolutions (both geometry and texture) are increasing at faster

(Remondino et al., 2008) to accurately reconstruct all the small letters. The image matching method is able to accurately model in high-resolution details visible in multiple convergent images and retrieve dense and precise 3D point clouds. The algorithm combines multiple matching primitives and various area-based matching techniques to exploit all the content information of the images. The matching algorithm derived a dense surface model which was afterward compared to the range data (Section 4.2).

## 4. RESULTS

### 4.1 Virtualization of the Great Inscription

The processing of all the range data required ca 2 months of work of 2 persons. The main problems came from the employed hardware and software which could not easily stand the huge amount of data. The triangulation-based range data were aligned and modeled at 0.3 mm (Figure 5) for the replica purpose. To prevent deformations during the registration of the single patches and avoid a wrong curvature of the Great Inscription, the high-resolution ShapeGrabber

scans were aligned with the Leica ToF data (5 mm sampling distance), providing a measure of the absolute registration error. The curvature of the wall, parameter useful for the physical replica, was also computed. Afterwards digital images were employed for the texturing of the wall and the inscription (Figure 6).

To scientifically prove the small depth of the letters, different profiles spread all over the inscription were also generated and the average maximal depth resulted ca 3 mm (Figure 8).

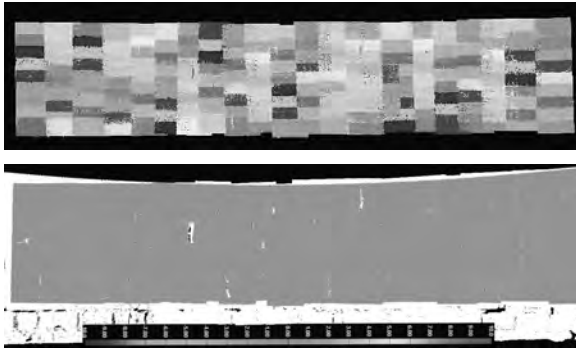


Figure 5: All the 212 scans of the entire inscription aligned and registered in Polyworks at 0.3 mm (above). The alignment of the two surface models (ShapeGrabber and Leica), done to prevent deformations of the ShapeGrabber data alignment and preserve the correct curvature of the inscription, gave a final standard deviation of 0.68 mm (below).

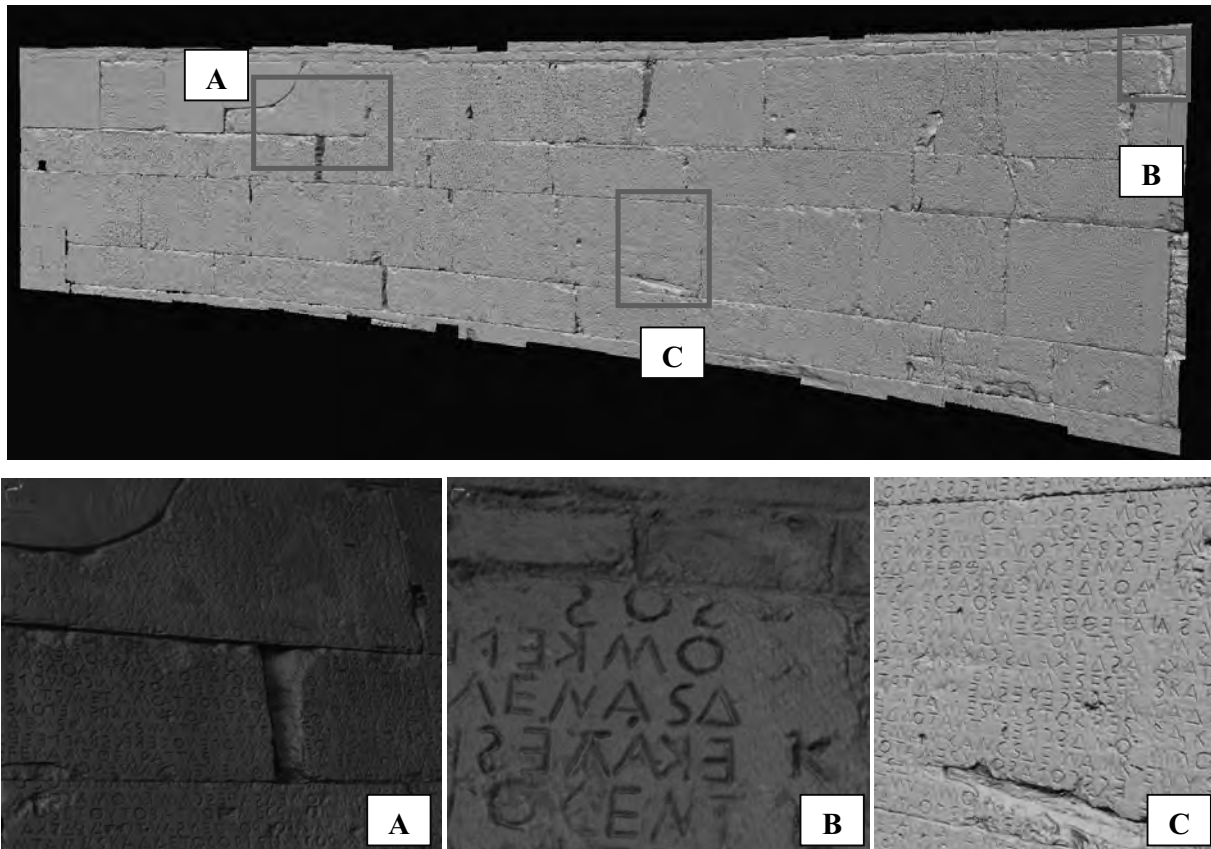


Figure 6: The shaded 3D model of the entire wall and some closer views of the Great Inscription modeled and textured at 0.3 mm.

Dealing with high-resolution data requires software with great capabilities in mesh generation, optimization and detail preservation. Indeed over-sampled areas (e.g. flat zones) do not require many faces while strong discontinuities do need the maintenance of a large number of triangles not to lose the modeled details. In Figure 7 a comparison between Polyworks and Geomagic's mesh optimization is presented. The same area was meshed with and without "advanced properties". It is clearly visible in the reported figures how Polyworks performs better as flat areas which were over-sampled are automatically reduced, while large surface discontinuities are correctly preserved with higher resolution meshes (Figure 7-C). Geomagic down-sampled almost uniformly the entire surface with no differences between flat and discontinuities areas (Figure 7-D).

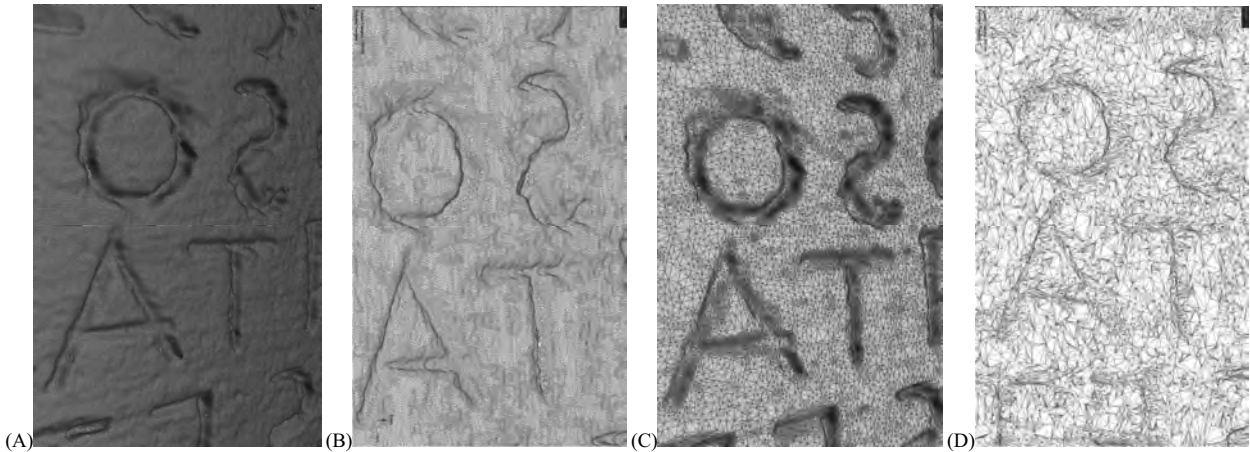


Figure 7: Meshes (at 0.3 mm) generated in Polyworks (A) and Geomagic (B) before and after (C and D respectively) the mesh optimization.

**4.2 Mesh simplification and geometric evaluation**

Beside the high-resolution mesh at 0.3 mm realized for the physical replica of the heritage, further models of the inscription at lower resolution were also produced, for faster and easier visualization. This required a sub-sampling of the data and therefore a loss of the geometric accuracy. Figure

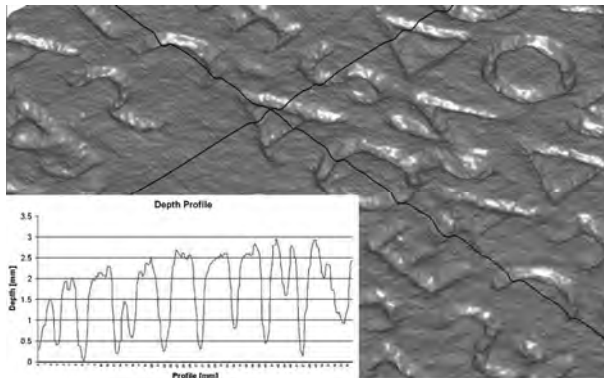


Figure 8: The profile of a small part of the inscription showing that the depth of the letters, in this area, has a maximal depth of ca 3 mm.

Table 2 reports the maximal and minimal deviation between the high-resolution and resampled meshes. Figure 9 shows a detail of the geometric comparison and the relative cross-section profile. The mesh at 1 mm (38 Mil polygons) is smoothing out areas with large discontinuities while the mesh at 0.5 mm (65 Mil polygons) is still keeping the details despite its 20% mesh reduction.

Although for visualization purposes the simplification might be very useful and not visible, for the project purposes it is not acceptable.

Mesh comparison	Max deviation	Min deviation
0.3 mm versus 0.5 mm	+0.407 mm	-0.268 mm
0.3 mm versus 1 mm	+0.916 mm	-0.745 mm

Table 2: Numerical evaluation of the loss of geometric accuracy and error introduced in down-sampling the mesh.

10 shows a visual comparison of part of the surface model at 0.3, 0.5 and 1 mm resolution respectively. The smoothing of the high-resolution mesh (0.3 mm), although visually not really apparent, has been evaluated comparing different profiles (cross-sections) on and the entire wall.

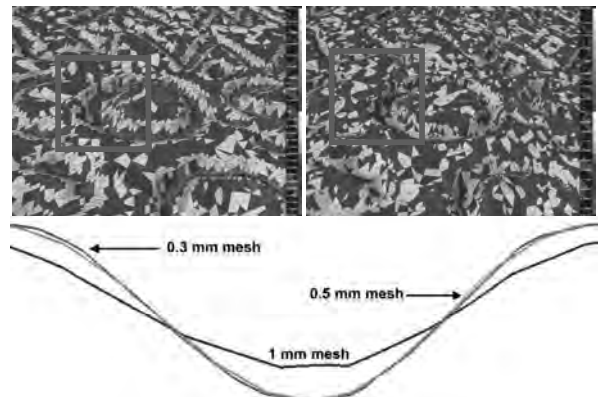


Figure 9: A closer view of the mesh comparison results. The derived profile of the boxed area shows the large smoothing effect of the mesh at 1 mm.

**4.3 Comparison of 3D modeling methodologies**

The surface models (at 0.5 and 0.3 mm) derived from the convergent images were registered and compared with the triangulation-based range data (Figure 11). The meshes comparison was performed in Polyworks/IMInspect. The achieved standard deviations of the differences between the triangular faces resulted 0.36 mm in the case of meshes at 0.5 mm and 0.14 mm between the meshes interpolated at 0.3 mm. These tests confirmed that we can model detailed areas with range sensors or images, achieving the same results in terms of accuracy and modeled details. The statistical value of the difference between the two surfaces is not indicating which surface model (or approach) is better but it provides simply an indicator of the very small discrepancies between the two surface models.



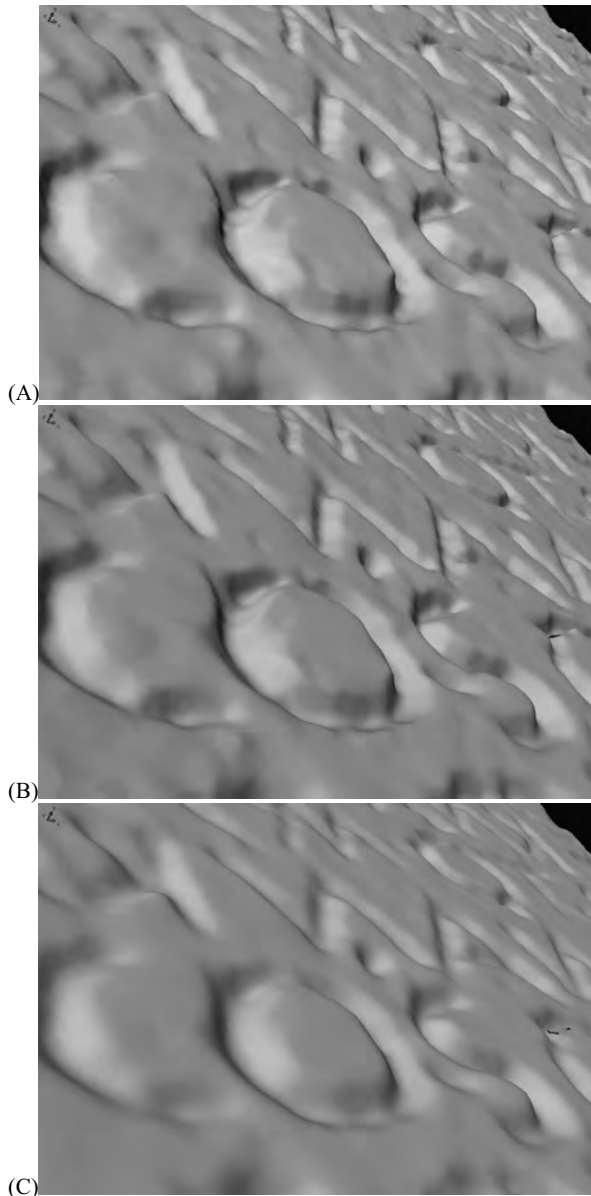


Figure 10: A detail of the high-resolution mesh (A) and the two reduced versions (B = 0.5 mm; C = 1 mm). The simplification at 1 mm lost almost all the small details of the letters.

#### 4.4 Virtualization of the entire heritage area

The range data of the entire heritage area of Gortyna were assembled mainly for visualization purposes and to contextualize the Great Inscription with its vaulted brick protection and the surrounding Odeion (Figure 13).



Figure 11: Part of the inscription (ca 1.2 x 0.6 m) used for the methodology's comparison (above). Two views of the surface model derived using a multi-photo image matching approach, shown as colour-code and shaded mode (below).

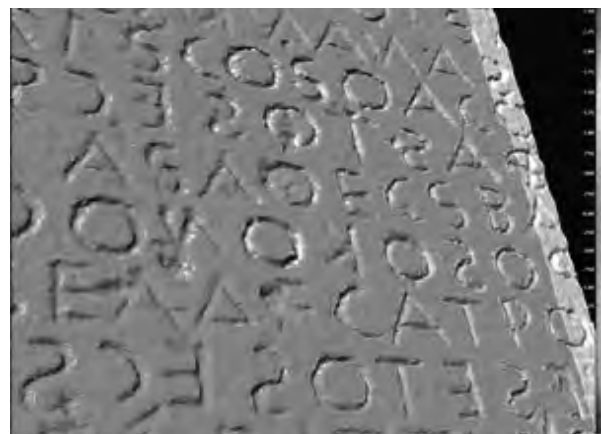


Figure 12: Result of the comparison between the range- and image-based surface models, which gave a standard deviation of 0.36 mm for the mesh at 0.5 mm. The colour legend on the right shows differences between +2mm and -2mm.

All the generated 3D models were afterwards merged together to produce a unique multi-resolution virtual model of the heritage area. Higher-resolution data in one level overrides and replaces the overlapped data found in previous levels of resolution and are loaded the closer we get to a detail. For the visualization of the large 3D data set different commercial software and research packages are under evaluation. Walk-through videos will be also produced for educational purposes and communication.

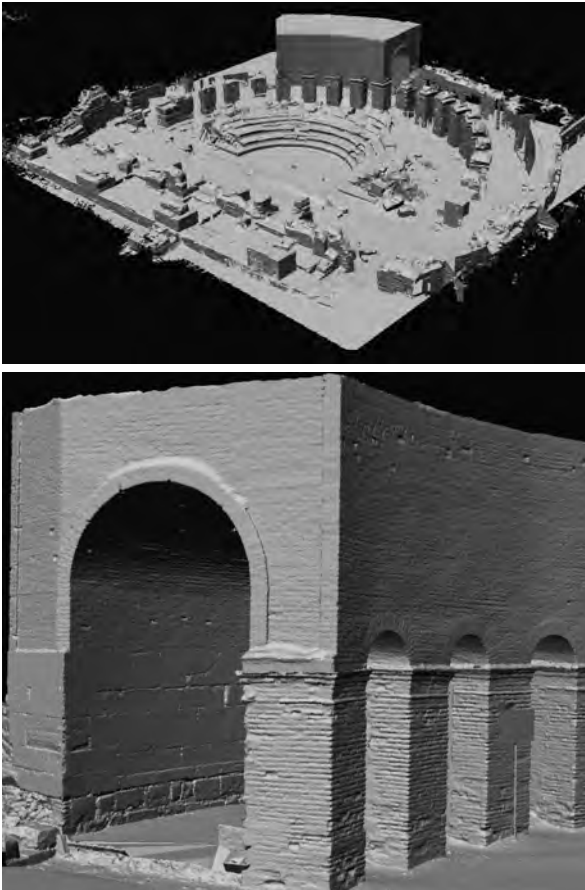


Figure 13: The entire heritage area of Gortyna (above) and a closer view of the 3D model of the vaulted brick protection containing the Great Inscription (below).

#### 4.5 Archaeological and structural studies

Following the project of the virtualization of the Great Inscription described in the previous sections, it is interest of the involved institutions to continue, using the recovered digital 3D model, with a study of the techniques of incision and with a deep analysis of the evidence of “suffering” of the monument. Indeed, after its discovery, the inscribed wall was covered with a vaulted brick roof which is probably causing damages to the wall itself. Different signs of the heavy weight on the engraved stones are also clearly visible simply looking at the inscription. Comparing the old evidence of the inscription (photographs, drawings etc.) and the newly generated 3D model, there is a good possibility to identify the critical points in order to develop a new project intended to prevent future structural problems and avoid further damages.

### 5. CONCLUSIONS

In this contribution the virtualization of the Great Inscription of Gortyna and its surrounding heritage area was presented. The big challenge of the project was the handling of the huge range data, the preservation of the small letters details and the integration of multi-resolution 3D data. A 80 millions polygons mesh at 0.3 mm resolution was produced for the physical replica of the inscription. Further studies on the mesh simplification, although useful for faster visualization and

handling, showed that optimizing and reducing the mesh at 1 mm would have removed most of the letters. The image-based approach for the 3D modeling of small parts of the inscription gave very satisfactory results and showed how photogrammetry can nowadays achieve very high-resolution, dense and accurate results similar to range sensors. The virtual model of the Great Inscription will now be used for replica purposes but also for archaeological studies on the incision techniques and a deeper structural analysis to prevent further damages of the heavy vaulted brick roof on the engraved stones.

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**7. ACKNOWLEDGMENTS**

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## THE SEARCH FOR THE LOST GARDEN OF THE COURT OF THE LIONS: RE-ANIMATION OF A HERITAGE LANDSCAPE

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**KEY WORDS:** Computer Simulations, Visualization, Islam, Court of the Lions, Alhambra, Heritage, Interpretation

### ABSTRACT:

The world heritage Moorish garden in the Court of the Lions in Alhambra, Spain, possesses few traces of its original verdant character. This study however, has capitalized upon a number of key clues to the landscape that once may have graced that famous enclosure. Through the application of digital re-animation, an interpretation of that lost garden has now been produced based upon these clues. This paper describes a research methodology that combines traditional archival documentation and literature review with innovative computer-generated suppositions of what may have constituted this 14<sup>th</sup> century heritage landscape. These digital simulations are tested against a framework of key 'evidences' and the final proposed heritage configuration has been interpreted using photorealistic imagery and animations. Building up from extant spatial analysis, archaeological studies, Quranic proscriptions for garden design, and period descriptions, both known and unknown elements of the garden were inventoried.

The study focussed to a digital investigation of the unknown elements including the amount of shade and the corresponding tree cover in the courtyard through illumination models as well as the layout of vegetation, both shrubs and flowers, in sunken planting beds. The photorealistic computer representation of the courtyard then combines the known elements with the conclusions regarding the unknown elements producing a startling interpretation of the 1391 garden within the Court of the Lions. This paper presentation thus represents both innovation in heritage landscape investigation, and in its interpretation. It will interest historians, computer experts and heritage conservators alike.

### 1. INTRODUCTION

A multi-cultural and multi-religious society flourished for almost eight centuries in Al-Andalus, the Islamic Spain, where remarkable accomplishments were made in architecture, horticulture, engineering, medicine, navigation, astronomy, mathematics, textiles, and agriculture (Scurr, 1991). Symbolic of this intellectual ferment was the Court of the Lions of Alhambra, in Granada, Spain, created at the peak of Islamic dominance in the region (Ruggles, 2000).

The Islamic garden is considered to be an amalgamation of many art forms and scientific achievements. It was conceived as an extension of the living space of architecture (Irwin, 2004). The garden-architecture relationship was intimately entwined creating one single composition (Van Zuylen, 1999). This integration between architecture and garden was particularly well practiced in the Mediterranean climate of Andalusia. Examining the condition of the Court of the Lions today however reveals a mismatch of structure and garden integration. The current simple gravelled courtyard does not harmonize with the intricate details of the surrounding architectural elements. In addition, the squared layout of the Court of the Lions (Figure 1) suggests a typical configuration of an Islamic garden, the four-part *chahar bagh* (the four rivers) of heaven described in the *Holy Quran* (Clark, 2003; Van Zuylen, 1999). Furthermore, the second verse of a twelve versed poem engraved on one of the twelve outer edges of the famous central Fountain of the Lions, translated in English, as "... and if not so; here is the garden containing wonders of art, the like of which Allah [God] forbids should elsewhere be found..." Not only that this verse mentions the existence of a garden, the verse describes the extraordinary beauty of the garden that God will not allow any place to be more beautiful than this one. Contrasting to this verse, the existing gravelled courtyard lacks the expected shade, fruit, scent and colour of plants (Nassar,

2002) which were also used as constant reminder to believers of the presence of God and the reward of the anticipated Paradise upon doing good deeds. The current state of the Court of the Lions lacks this strong physical-spiritual relationship and symbolic content. Its lack of vegetation also does not reflect the innovative hydraulic engineering which brought water to the courtyard and its centrally located Fountain of the Lions.

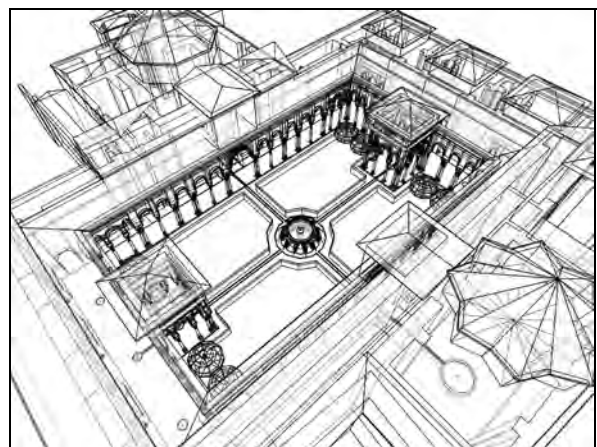


Figure 1: Computer model of the Palace and Court of Lions Complex (looking North-East)

From a landscape architectural as well as a Quranic point of view, there is much to suggest that there was once an elaborate garden within the Court of the Lions. This incongruity became the genesis of a piece of research that first turned to traditional sources but was confounded by the lack of period descriptions, as well as the likely erasure of the original Islamic garden

during the *Reconquista* by the Christian rulers started in 1492, after centuries of Moorish control (Nuere, 1986, citing D. Leopoldo, page 92; Dickie, 1986; Irwin, 2004, citing Ford's 1845, *A Handbook for Travellers in Spain*, page 145).

It was in an excavation to stabilize the surrounding structure's foundations in 1902 that provided the strongest evidence suggesting that the courtyard would have had a cultivated garden during the Arab occupation. During that dig, the original Moorish soil height was discovered, some 3 feet (80cm) below the existing pavement level (Dickie, 1976). This was a sunken planting bed, a typical garden feature for water conservation used during the Andalusian period. The lowered ground level provided a sheltered reservoir supplying needed water to plant roots in an arid climate (Clark, 2004). A garden was suggested and the research took root.

## 2. RESEARCH METHODOLOGY

As a result of the lack of reliable documentary descriptions of the garden that survived during the Arab time, this research employed numerous other sources of descriptive evidence of a potential garden in the Court of the Lions (Figure 2). Three aspects were seen to be the keys to unravelling the landscape structure: variations in shade; tree species and alignments; as well as shrub types and their arrangements. These elements were dependent and closely related variables. For example, in order to determine the types of shrubs that were used, it was necessary to determine whether trees were present or absent at the time. Once it was determined likely that trees were present, it was then possible to explore the shade density generated from different trees and then decide upon the corresponding shrubs which would flourish or not on the basis of these shade densities. Figure 3 outlines such investigative process. A series of connecting questions were thus posed for each of these garden components in determining the likely Islamic configuration of the Court of the Lions. To test these propositions three different types of computer simulations were employed, namely conceptual, illumination and photorealistic models. These were used throughout the process as virtual instruments for testing hypotheses and for presenting the research findings.

The starting point of these cascading suppositions and virtual environments began with the essential commodity of shade – a key to microclimatic design in the intensely hot climate of southern Spain. The stages of inquiry followed using both physical, metaphysical evidence tested with computer simulations.

## 3. COLLECTED EVIDENCES

### Physical Evidences

**3.1.1 Marble Column Deterioration:** Without tree cover a hostile environment has been setup for the structural elements of the courtyard. The continuous action of frequent thermal changes is seen to be the main cause of the white marble column deterioration observed in the Court of the Lions (Rodriguez-Gordillo & Saez-Perez, 2006). The columns along the north arcade in the courtyard are affected by different degrees of deterioration, particularly in the form of superficial scaling and micro-cracks. The same level of deterioration of columns is not noticeable along the east, south and west arcades. Studies carried out by Galan *et al* and Saez (both cited

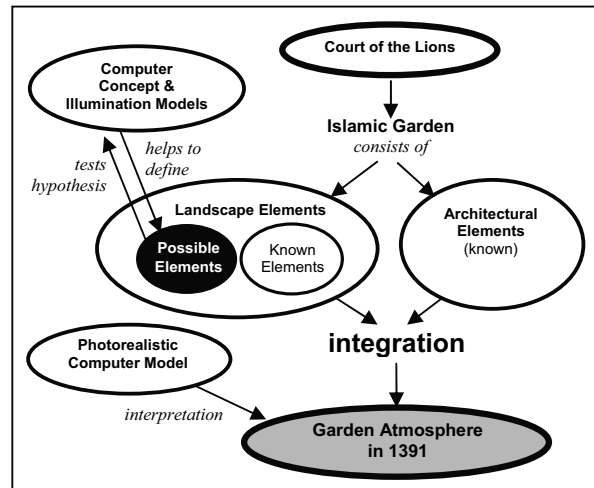


Figure 2: Generalized Research Framework

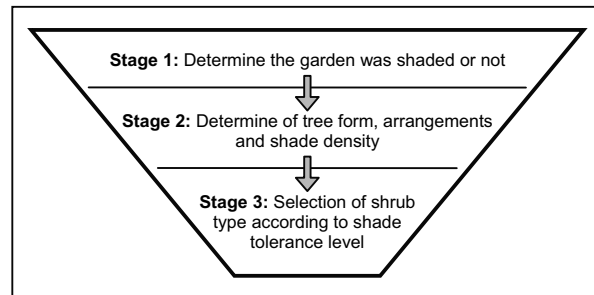


Figure 3: The Investigation Process

in Rodriguez-Gordillo, 2006) examined the intimate relationship between the type and the degree of deterioration presented by each column, as well as the thermal variation to which it has been continuously subjected to through sun exposure for approximately 500 years. The continuing lack of shade from trees for approximately five centuries increased the range of temperature extremes and eventually initiated the cracking and deterioration of the marble. Not only that this time frame seems to support the *Reconquista* tree removal, these scientific studies indirectly suggest that shade was present five hundred years ago during the Islamic Spain period.

**3.1.2 Bio-deterioration Of The Lions:** The colonization of the surface of the lions by mosses and fungi is also causing erosive processes (Sarro *et al*, 2006). In a study of microbial deterioration of rocks and marble monuments of the Mediterranean basin, Urzi pointed out that "... surfaces exposed to direct sunlight, and having a slope that favours the rain run-off, are more subject to bio-corrosion processes than other surfaces located in sheltered areas." (Urzi, 2004, 443). This would also suggest that the presence of shade from trees would possibly help to slow down the bio-corrosion processes by minimizing the direct sunlight exposure to the marble.

**3.1.3 Physical Height Of The Court:** The height of the surrounding colonnaded arcades and enclosures of the Court of the Lions is not excessively tall. The Muslim designers knew that such a short enclosure "admits more Sun in both summer and winter, and admits more wind and radiates more easily to a cold night sky. Without intervention by either plants or inhabitants, the shallow courtyard [short surrounding structure]

in a hot dry climate would be harder to cool on a summer day, but probably warmer on a winter day” (Reynolds & Lowry, 1996, 126). These proportions suggest that if there had been trees present the amount of direct exposure of the sun into the Court would have been minimized and the surfaces in the courtyard would have been cooler.

**3.1.4 Microclimatic Design:** The inland areas of Andalusia have hot and dry summers with temperatures ranging from 38°C to 42°C (Carrasco & Reynolds, 1996). The temperature in late afternoon can go up to 44°C to 45°C during heat waves with the lows in the early mornings hovering around the mid-20°C (*ibid.*). The presence of trees in a courtyard could provide shade to ameliorate these thermal extremes. Trees in courtyards not only help control solar gain into the building, but also shade the site, reducing surface temperatures. The leaves of trees intercept the solar radiation before it strikes the building and dissipates the absorbed heat by evapotranspiration. The tall trees with a wide canopy, rising above the roof, could not only provide the shade but it would also create a semi-barrier between the courtyard and the ambient air temperature above. This reduces the air exchange on windy days. This also helps to retain the moisture in the courtyard. As plants transpire, they lower the air temperature in their vicinity while raising the air’s relative humidity. This cooler and humid air in hot-dry climates represents increased comfort (Reynolds & Lowry, 1996). Hence the presence of shade from trees in the Court of the Lions would likely have helped to lower the daily mean temperature.

**Metaphysical Evidences**

**3.2.1 Water in the Quran:** “Gardens underneath which rivers flow”. This verse is mentioned over thirty times in different chapters in the *Quran* (Nassar, 2002). It suggests that water should be protected from direct exposure to sunlight for water conservation. This was turned into a reality across a range of cultures and landscapes that the Muslim empire controlled. Their knowledge of hydraulics was put to particular use in the many arid regions they occupied.

**3.2.2 Perpetual shade in Paradise:** Perpetual shade is a common feature to the Quranic description of Paradise (*Quran* 56:30) and the garden embodies the environment of that ideal place with no extreme heat from the sun or bitter cold (*Quran* 35:20-21; 76:13). Indeed, shade is a significant feature in paradise gardens. In the *Quran*, God promises shade to His faithful believers. “Spreading shade” is an expression used in the *Quran* as part of the reward that awaits the believers and righteous. “We shall admit them to shades, cool and ever deepening” (*Quran* 4:57). These phrases can be found throughout the *Quran* as a reminder of the reward and encouragement for people to do good deeds. This suggests that an Islamic garden needs to reflect the Quranic idea of shade.

From this physical and metaphysical foundation three ranges of computer simulations were made. The first was a simulation of illuminations cast from differing shade patterns. The second and third explored a variety of ways the trees and then shrubs would correspond with the shade patterns.

**4. COMPUTER SIMULATIONS**

This study made use of the computer visualization technology as investigative and presentation tools. It relied heavily on the use of three types of computer modeling namely: Concept,

Illumination and Photorealistic Models. Figure 4 shows the software used for these three types of computer models. These computer simulations were invaluable virtual tools for this study and were transparently used throughout the research process. These virtual test instruments helped immeasurably with the research findings and were essential to the outcome.

Model Types	Software	Used for
Concept Model	SketchUp 5; SketchUp 6 Pro	Concept model and interactive exploration
Illumination Model	Lightscape 3.2	Illumination studies of architectural elements
Photorealistic Model	VUE 6 Infinite	Photorealistic images and animations

Figure 4: Types of computer model used for this study

Due to the scarcity of architectural drawings of the Palace and the Court of the Lions, the following references were the only two architectural sources collected and used during the period of this study:

- Plan drawing and column details from: Fernandez-Puertas A. 1997. *The Alhambra: From the Ninth Century to Yusuf I.* SAQI Books, U.K.
- Elevation drawings from: Goury J. and Jones O. 1842. *Plans Elevations, Sections and Details of Alhambra.* London, U.K.

These valuable technical drawings, together with over one hundred high resolution site photographs taken by the researcher on July 5, 2007, became the source of reference for creating the three types of proportionally accurate computer models of the Court of the Lions.

**4.1 Defining location, date and time settings**

Prior to conducting the computer simulations, all computer models were calibrated according to the following settings for establishing technical credibility.

**4.1.1 Location Setting:** In order to simulate the shade conditions accurately, the virtual location of all computer models was set to Latitude: 37°10’37.73” N and Longitude: 3°35’21.3” W which is the geographic coordinate of Court of the Lions according to Google Earth.

**4.1.2 Date and Time Setting:** The chosen date and time for computer simulation was June 21<sup>st</sup>, the Summer Solstice. It is the sun’s position at its highest point in the sky producing the strongest solar radiation for the entire year. All objects would cast their absolute shortest shadows of the year. By knowing the height of the building facade and the sun’s angle of the Summer Solstice at a geographic location, it was then possible to find out the minimum height of a tree at a specific location in the Courtyard that can cast a shadow long enough to shade and to protect the entire height of building facade from solar radiation (Figure 5). The figure also shows that the tree height required to cast shade would depend on its relative distance away from the building. The further the tree is from the building, the taller the tree is needed to cast shade on the building facade.

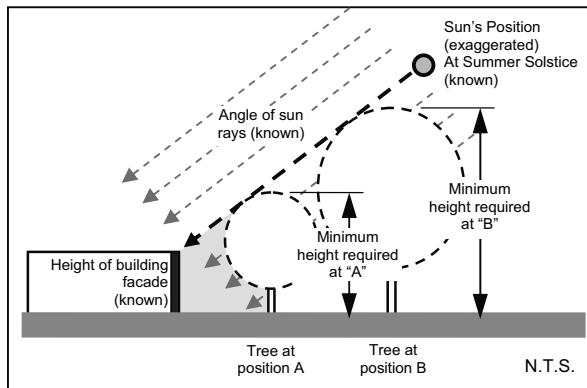


Figure 5: Conceptual diagram for determining minimum height of tree at different locations for shading an entire building facade on Summer Solstice (June 21)

## 4.2 The Computer Simulations

**4.2.1 Marble deterioration and shade protection:** An illumination model refers to the calculation and simulation of light energy that reaches the receiving surfaces. This model was employed in the computer simulation created for a virtual Court of the Lions where first no trees were located in the space. The sunlight was simulated at noon time on Summer Solstice (June 21) when the sun rays are the strongest during the day. The model showed the light energy received on the north facade of the promenade and was very high when compared to the other three sides of the promenade (Figure 6). The result of the simulation corresponds to a diagram showing the level of individual column damage within the courtyard where the columns on the north facade are effected most severely (*Estudio Constructivo-estructural de la Galeria Y Columnata del Patio de los Leones de la Alhambra de Granada*, pp. 80-81).

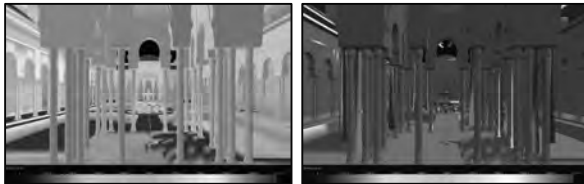


Figure 6a (left): Light energy deposition relative unevenly on facades with no trees. Figure 6b (right): Light energy deposition relative evenly on all facades with palm trees.

Note: original images in full colour

A series of simulations were then staged with shade provided by different configurations and species of trees.

### 4.2.2 Tree Type, Arrangement and Shading Simulation:

This stage required the formation of the “Rules of Trees” which were used as the parameters for further computer simulations. These “rules” were formulated on a summary of information collected from a variety of books and research articles which relates to the Court of the Lions. A listing of these books and articles is shown in the Reference section of this paper. Sun’s angles, tree heights and their related canopy size were used in the simulations with an over-riding ‘rule’ that the plantings should not interfere with the surrounding architecture in terms of sight lines (Irwin, 2004; Van Zuylen, 1999). By using a computer model of the Court of the Lions the relationship between tree dimension (tree height and width of canopy) and

sun angles were tested. It was found that when the sun is at its zenith on Summer Solstice on June 21, it would require a deciduous tree with a minimum height of forty feet (12m) tall to shade the north facade of the promenade (Figure 7).

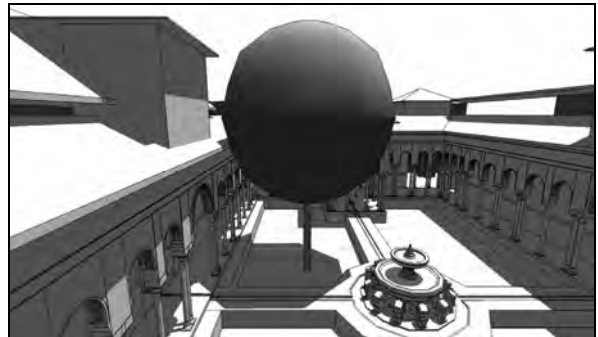


Figure 7: Dimension of a typical 40 ft (12m) high tree placed within the Court with its shadow covering the entire height of the north facade on Summer Solstice (June 21)

For simulation purposes two deciduous trees were located on each of four quadrants for a total of eight, geometrically arranged in the courtyard. Although this arrangement created full shade in the courtyard, it violated one of main rules with the canopy of the tree visually blocking all the facades of the surrounding highly decorative arcades (Figure 8). From the computer simulation, the only solution that was found to satisfy all of the “rules” was the selection of palm trees.

By replacing each deciduous tree with four palm trees of the same height, similar canopy coverage was created (Figure 9) while preserving unimpeded view of all four facades (Figure 10). This was made possible because the canopy of palm trees was positioned well above the upper part of the facades. A separate computer illumination model with the presence of these thirty-two palm trees produced an evenly lit and partial shaded courtyard with uniform illumination across all facades (Figure 6b). This simulation confirms the installation of palm trees would have drastically reduced the received sun’s energy on the north facade when compared to the illumination simulation with no trees. This suggests that the temperature extreme on the marble surfaces would be less as would its deterioration. Furthermore, it also echoes the Quranic description mentioned earlier of no extreme heat from the sun (*Quran* 35:20-21; 76:13)

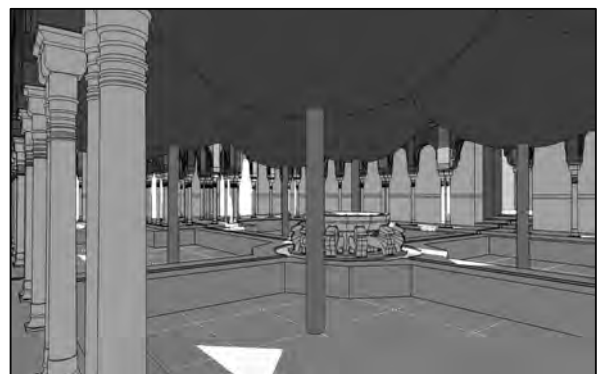


Figure 8: Looking North-West along South Arcade (Deciduous Trees version)

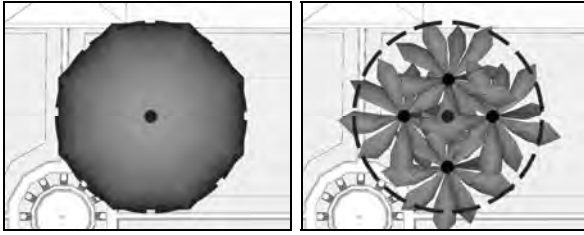


Figure 9: Tree configuration comparison between deciduous (left) and palm (right)



Figure 10: Looking North-West along South Arcade (Palm Tree version)

**4.2.3 Shrub Types and Arrangement Simulation:** As with the trees a set of “Rules” were also established with the placement of shrubs within the virtual environment of the Court of the Lions. These “Rules of Shrubs” were created as parameters for the computer simulations. Two of the main rules included: the shrubs need to be planted in the sunken quadrants to produce a carpet effect that would not impede views to the fountain (Irwin, 2004). The shrubs also needed to be able to survive in partial shade conditions.

The simulation showed shrubs like myrtle could be used for the “carpet effect” with smaller orange trees, planted on each quadrant of the courtyard along the north and south side of the pavilions. Both of these plants produce a pleasing scent with the fruit of orange trees within reach from the pavilion. The arms length location of the orange trees also fits the description from the *Holy Quran* where fruit is positioned close by. “... [S]ince its [blissful] shades will come down low over them, and low will hang down its clusters of fruit, most easy to reach.” (*Quran* 76:14)

## 5. CONCLUSION

This research represents a methodical search for a lost heritage landscape. Through a series of connected inquiries of physical and metaphysical evidence a world of scented and colourful shrubs with oranges plucked from low hanging trees has been re-animated. The exploration of what could have been the environmental qualities of a well-known Islamic courtyard was at the centre of this study that employed primary sources, scientific studies, Quranic verses, and computer modelling. A glimpse at a no longer extant yet highly probable piece of exquisite Islamic design has been created.

All the senses can be engaged in this kind of heritage investigation. The dappled shade of overhead palm trees, the sounds of water gurgling from the mouths of twelve lions, and the reflected light on the polychromatic facades of the promenades is sensed in the virtual environment created in this study (Figure 11 and 12). This was the luxuriant environment that Sultan Mohammad V would have experienced and enjoyed in the year 1391 before he died. He built the courtyard for his pleasure, a space which also reveals the vividness of his life and times with an underlying message of peace. He was known for his preference for diplomatic negotiations rather than war (Fernandez-Puertas, 1997b). Ultimately it was this peace which provided him the personal freedom and creative opportunities to build an engineering and architectural marvel, the Palace and the Court of the Lions. Today the Courtyard sits at odds to that historic place for aesthetic and religious repose and this research presents a way to piece together what could have been and what still could be. This research presents a method of heritage investigation that employs both conventional and virtual methods of inquiry bringing together the power of insight and delight.



Figure 11: Photorealistic simulation of the interpreted garden atmosphere in 1391

Note: The above two images were from a photorealistic computer animation which shows the sun light penetrates into the Courtyard through slight movement of palm leaves (left), creating dabbling shade effect within the Courtyard (right)



Figure 12: Visual comparison between site photo taken by the researcher in 2007 (left) and computer photorealistic simulated image (right) from similar viewing angle

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## DIGITAL RAVENNA. EXPLORING THE TOWN THREE-DimensionALLY

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**KEY WORDS:** Urban Surveying, Urban Heritage, 3D City Models, Architectural Photogrammetry, Built Environment Awareness, 3D data-base, 3D PDF

### ABSTRACT:

The purpose of this research is the creation of a three-dimensional model of the city center of Ravenna. The creation of a three-dimensional model offers several advantages: first of all, it allows to deepen the knowledge and to represent the city center in its spatial and historical complexity; moreover a three dimensional model represents a tool for interactively explore the virtually reconstructed space, to visualize the archeological sites; to emphasize the most relevant buildings; to simulate interventions on buildings of the urban landscape.

To build this model we defined a method based on various aspects concerning to surveying procedures (encoding and zoning, instruments and measurement techniques), the graphical elaboration (standard coding graphics), the modelling criteria and arrangements to display with a public graphical format (\*.PDF).

The generation of a three dimensional model provides an important spin-off for the organization of the working documents in a well structured whole. The documents themselves become analytical and representational tools of the urban environment.

The results obtained in this work constitute a preliminary research phase (in progress and which is approximately one third of the whole Center). The analysis of this framework allows to program future activities, defining methods and necessary tools. Future developments concerning the mapping, the highlighting of infrastructural components of the city and improving the representation of the key sceneries (gardens, green spaces, paved surfaces...).

### 1. INTRODUCTION



Figure 1: Map of Ravenna, 1629

The increasing interest in the protection and valorisation of the historical urban morphology led to experiment different analysis and representation techniques, improving knowledge and urban planning.

Urban regeneration and recover of the historical city, as that of the contemporary one, has a fundamental importance and lead to face complex matters. New methods for representing knowledge and reading the urban landscape are needed. These methods must develop both being functional in planning proposals and being light-weight tools to keep trace of the urban scenery, allowing to understand and interpret the existing buildings (morphology, spaces, architectural elements), to

recognize and represent qualitative phenomena connoting the town and determining its identity.



Figure 2: Ichonographia Urbis Antiquae Ravennae, 1690

Growing attention to preservation of historic urban constructions is taking place, in Italy as well as around European area, according to different methods of testing and depiction and communication; so far, these methods are finalized to urban planning and knowledge.

Developed environment quality requirements and new demands from communities are giving back to Architecture the key assignment to assure life settings, often neglected to quantitative and economic requests. Inner city requalification, as well as contemporary city one, are main topics which

demand very knotty answers. New urban environment knowledge methods are urgently necessary: we need new skill processes aimed at a proper reading of existing systems – architectural space, details, etc. – and at a proper reorganization and representation of qualitative characters. In fact, these elements are of crucial importance and we believe have to be taken into consideration, as they typify a city and define its identity.



Figure 3: “Rocca Brancaleone”: QTVR

One of the main difficulties nowadays is to identify a standard and robust way to arrange and organize data. An easy and rapid system for collecting, organize, highlight and graphically represent information has been developed for this purpose.

The first step was characterized by the constitution of a methodological body to define an informative tool on which basing programming actions, control and interventions, through a deep analysis of the urban, environmental, and building system.

The matter is to define the methodologies for engineering an informative system, potentially capable of carry out: organizational functions such as selection, articulation and coordination of the informative flows; operative functions, such as decision support functions or interventions activities control. The system has to handle complex relationships between compound infrastructures, urban systems, aiming to be both a support tool for the regeneration of urban scenery and a tool to safeguard the historical peculiarities characterizing the place. On the one hand this tool has to organize, archive and deliver information, on the other it has to continuously monitor the site characterization, allowing programming of critical interventions and being an interface between the building, its features, its needs, its geographical and historical collocation and the user. In the actual situation, standards for data organization are difficult to find, and the research aims at building a data base system for easy and fast data modification and integration. Therefore, the main goal is the formation of a methodological background for the definition of a "information tool", on which founding the actions of planning, controlling, building. This happens through a detailed analysis of urban, environmental and building systems.

Methodologically, information systems should have the organizational function of selection (logistics) to support decisions and control intervention activities. The system should be able to manage the complex relations among infrastructures, building complexes, and urban fabric, in order to support the rehabilitation of the urban image. The goal is also to safeguard the system of invariants which characterize the site, according to which the interventions should be measured in relation to local peculiar elements.

This instrument is conceived not only to be able to give information, but also continuous control, finalizing it to the critical planning of interventions, with an interface among operators. Recent scientific literature highlights that description, visualization and representation techniques are addressing towards 3D modelling in every field. Beta versions of the newest geo-browsing software such as Google Maps or Maps Live are close to get production versions.



Figure 4: “Piazza del Popolo”: QTVR

This trend has been noticed in architecture as well, especially among the highest levels of planning production, in the visualization and representation of the project, starting directly from the model rather than from bi-dimensional drawings and orthogonal projections. A model-based approach is not new: the novelty is represented by the ease with which three-dimensional space can be represented and explored in the digital space; by the possibility of manage and visualize data and planning themes separately or together. While at a spatial level it is possible to experiment complex geometric representations as the sum of actions starting as simple geometrical entities, studying the interactions between the building and its context involve experimenting many features and parameters such as the simulation of noise reduction, the lighting environment in different light conditions, the natural ventilation, the colours of the buildings, etc. This research deals with these considerations to build a robust framework on which experiment and improving techniques in the following directions: 3D modelling, together with traditional representations, can be an important and effective resource to understand, represent and explore the complexity, of the urban landscape.

The architectonic documentation state can represents a serious problem in the operative praxis. It can be sometime lacking, often massive, very often characterized by type of document of different nature, having different aims. It can be constituted by drawings, papers, archive documents, pictures, and many others. These documental representations are highly heterogeneous.

Trying to organize this paper to study the town highlights the difficulty to render its complexity, especially if one is concerned with its representation or with interventions needs. Moreover, the news tools used to plan recover purposals are generally highly sectorial, and based on the elaboration of mainly numerical data. The main matter we had to deal with, concerns the current urban and architectural heritage documentation, which is not qualified to describe the real complexity of architectural environment and urban convolution, or to manage with new involvements, and hold up troubles. For these reason it has been necessary to use new technologies and new ways of representation, aiming at producing drawings capable to synthetically express the biggest quantity of information available; within them, the three dimensional

urban-scale representations, together with other well experimented approaches such as photogrammetry, direct and indirect surveyings, electronic archives constitute a very effective method.

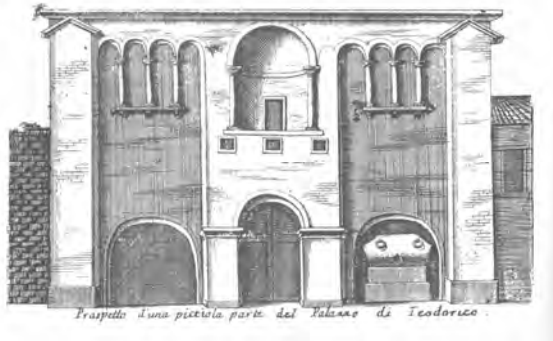


Figure 5: Front of “Palazzo di Teodorico”, 1700

The project purpose was to snap city background portrait by a coordinate use of different analysis methodologies: topographic surveying, different graphic and photographic designing, digital pictures processing, mosaic photoplans, 3D virtual models of built-up space and an inclusive data-base [DB] of inner-city buildings facades, going over simple plans scheming. This research deals with experimenting new methodologies for recovering, tracing and regenerating the urban estate. The study was conducted by the research team led by L. Cipriani and composed by M. Ballabeni, E. Modde, M. Roberto in collaboration with the Flaminia Foundation of Ravenna, the Faculty of Engineering of Bologna, Department of Ravenna and the Research Area of the Province of Ravenna.

As a first step of a long term study, the present contribute represents an analysis of the historical centre of the town of Ravenna. Preliminary results of this study were presented in the Conference “Ravenna Ricerca 2008”.

## 2. THE DIGITAL MODEL

The main awaited result of this study was the generation of a digital model of the historical centre of the town of Ravenna. The initial construction of the model provides some colourless volumes; then textures will be attached to reconstruct buildings, starting by the main ones. Secondly, this work aimed at experimenting different systems of exploration, visualization and interoperability among different sources of electronic archives.

### 2.1 Construction of 3D digital model

The first characteristic assigned to the model deals with the ease of realization, by means of a very common, widespread software, addressing potentially vast audience of users, granting a good quality of representation and visualization. The research team tries to simplify the architectural complexity maintaining irregularities (i.e. vertical and horizontal alignment of windows and doors, irregular perimetral profile of walls, architectural order and ornaments). The 3D reconstruction is based on an accurate surveying of the existing buildings, and, within certain limits, it reconstructs irregularities. For this reason, traditional techniques and modelling systems were preferred to other specific applications probably faster but less flexible.



Figure 6: Codification of blocks and phases of construction

To build this model we have defined a method based on the following aspects:

- the city center has been divided in multiple areas and each area has been surveyed
- a two dimensional surveying has been built by using photographic surveyings
- several graphic bidimensional drawings surveyings have been done
- to merge surveyings, a graphical coding standards of 2dimensional drawings has been applied; moreover a coding standard showed its usefulness in fixing different level of detail.
- the orthographic plan joined with the 2dimensional drawings of the fronts allows to shape a three dimensional object
- Different criteria have been established to merge several files into an organized master file
- The final model of the city center has been exported in \*.pdf format. The last version of this format (8.0), allows the user to visualize and browse the model in several modalities.

The model will be described through procedural steps.

**Identification and tagging of urban blocks:** The available vectorial aero-cartography, with a level of detail of 1:1000, represents the common base on which was possible to reference the model. Using the cartography regarded: coding urban blocks, naming them in an unambiguous way; sharing and linking general surveyings data with partial surveyings (i.e. altimetry quotas and perimeter blocks profile); highlighting urban divisions (constituted by one or more blocks, depending on their sizes); assigning urban divisions (or part of them) to different workgroups; each workgroup had to carry on surveyings and modelling procedures.

**Urban blocks surveyings:** This step has been accomplished integrating vectorial aero-cartography data with direct surveyings. This procedure allowed generating a ground floor plan of the buildings. Photographical surveying of the exterior facades (street front) have been collected and electronically linked to the plans. As a general and shared approach, the discrepancy between the direct surveying and aero-cartography data has been resolved choosing the general sizes coming from the latter, being assumed as a common geographical reference. On the other hand direct surveyings have been collected, organized and corrected to enrich the model of a depth that the map doesn't have.



Figure 7: “Palazzo di Teodorico”: photo-stitch

External surveyings have been taken with a level of detail compatible with the scale 1:100. In particular, to have a wider coverage of the building, considering the narrowness of many streets, a software (PTGUI) was used to stitch partial photos: this simple procedure, allowed to obtain single photos of the buildings, to use as a bi-dimensional restitution of the façades.

Sizing the elements was possible by means of previously taken measures and modular arrays of elements of known sizes. The experimentation of other kind of techniques, such as the 3D restitution from photographs only using PhotoModeler, has been evaluated, tried and discarded, judged not advantageous in terms of time and number of photos to manage.

**Graphic encoding of the two-dimensional drawings:** Even if the primary goal of this research phase was the generation of a 3D model, an intermediate phase showed to be necessary. This intermediate phase was constituted by the bi-dimensional restitution of façade views. Even in this context façade views don't decrease their importance as tools; they represent an important document, usable in different contexts and for different goals

For this reason, and for better managing the generation of the 3D model, it has been engineered a reference model capable to code the modality of re-drawing the reality, the graphic symbols and the organization of working plans, in order to obtain from a single work, different scales of detail. To obtain a homogeneous project of the façade views, a highly typized graphical coding, and simple procedures on the redrawing modalities of out-of-view objects have been established. The reduction of the error margin in applying graphical coding have been accomplished by using a pre-organized template file.

Appropriate graphic encoding and simple procedures on the modality of rendering out of plan objects was necessary to obtain a uniform and homogeneous rendering. The reduction of error in the encoding application has been accomplished by creating explanatory graphically organized templates.

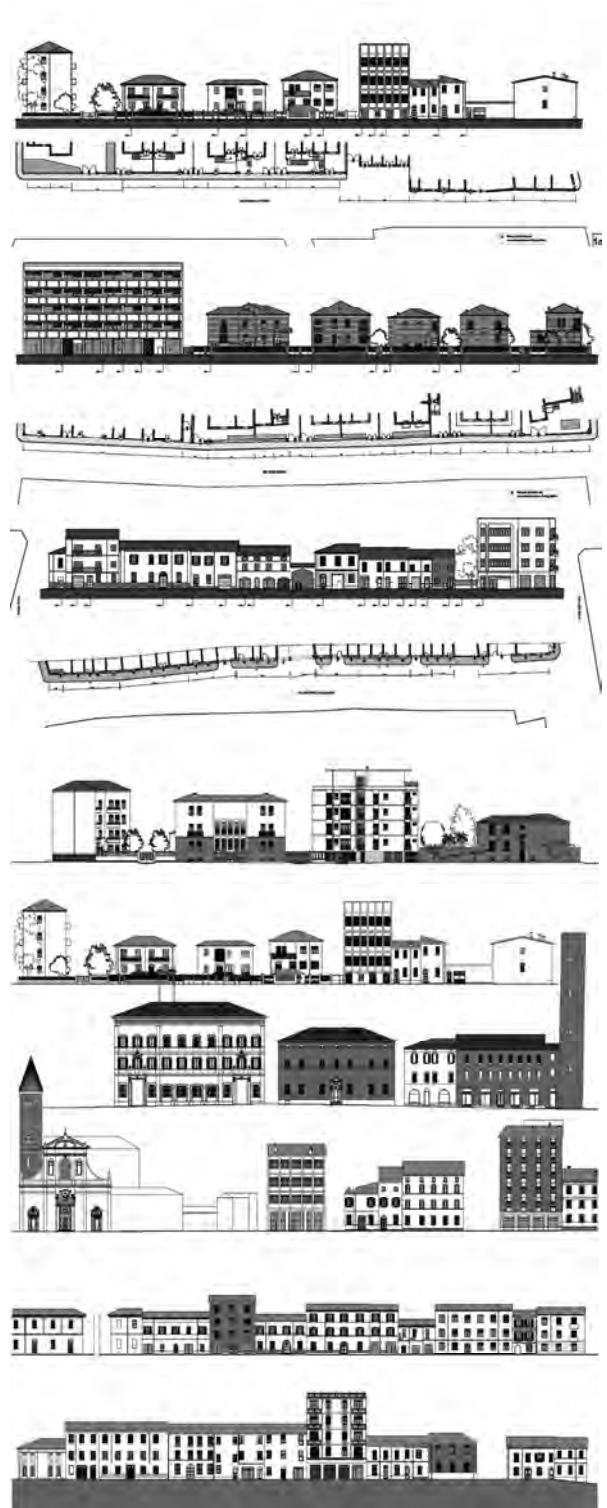


Figure 8: Façade views

**Building the physical model in wood:** First of all, regarding the reconstruction of volumes at stake and mutual relations, and as a moment of investigation related to the physicality of places, a physical model of study in wood (balsa) was drawn up. The model is drawn to a scale of 1:333, and the final size will be approximately 4 x 5 metres.

The use of this model together with a digital one, allows to pursue interesting considerations relating to the figures of the places on static and dynamic views.



Figure 9: Model in wood (balsa)

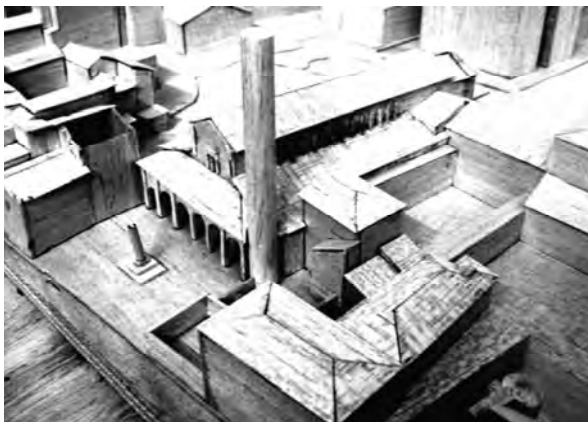


Figure 10: Model in wood (balsa), detail

It is clear that this stage is very costly and takes a long time but important meaning in education related to research, and the model can be used during public exhibitions.

**The modelling of block:** The modelling of block was conducted in a conventional manner using the planimetric base and elevations plans. The private interior spaces of the blocks were developed only at a volumetric level. As with the two-dimensional views, common modelling rules have been defined and harvested in a model example; again, the greatest difficulties are related to the complexity and heterogeneity of the elements of urban space.

The model has been defined taking into account the following objectives: possibility to display items from elementary to detailed volume; lightness of files; line hidden final rendering

or shaded in tones of grey. On the lightness of file processes capable of simplifying the representation of the reality while maintaining its recognizability were privileged. In this sense, some elements were reduced to two-dimensional objects considering the negligible difference in the final display (eg bars, railings and thickness of window frames...). This last step was critical for many of the non-coded elements (e.g. shelves, cornices, tympani, balustrades ...), developed in different ways by different surveyors.



Figure 11: Digital Model

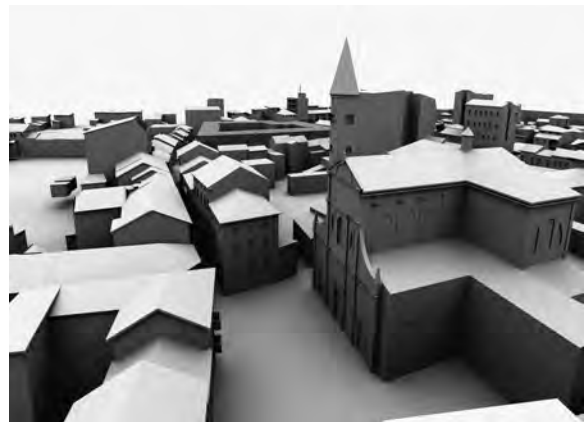


Figure 12: Digital Model

The solution, taken in the later stages of research, could lie in a sufficiently extensive repertoire of proposed solutions for the modelling of these elements. About ground modelling, the non-planarity of the ground, however characterized by very little gradients (about 2 meters in maximum height difference), has taken into account. The chosen solution is that of modelling through elementary polygons. For characterization of roofs aerial photos and [www.maps.live.com](http://www.maps.live.com) supplied photos were used and integrated with on-sight and photographic surveyings.

The choice of a conventional character modelling is also linked to educational experiences developed in synergy with the research; in subsequent phases it would be necessary a comparative study, for example, between this approach and use of parametric CAD. The 3D models were organized as a reference file linking individual models of blocks to a single master file.



Figure 13: Detail of a digital urban block



Figure 14: Detail of a digital urban block

## 2.2 Important spin-off

The documents created to build the model have an important spin-off: the documents themselves become analytical and representational tools of the urban environment.

The most important material is represented from the production of two-dimensional front road views. This work allows showing street buildings in its entirety, thus to observe and study the urban streets and to appreciate the single building inserted into the system of facades. The result is a framework of knowledge that recomposes heterogeneous information and returns, clear and concise, the morphology of the town.

Secondarily, to further deepen this type of representation, a catalogue of the most important and significant buildings have been developed, increasing the level of detail. (plan and elevation, scale 1:50).

Finally, some of the photographs made for the redrawing of fronts were organized to build a catalogue of significant architectural elements (doors, windows, portals ...).

The photos of the chosen items were "straightened", dimensioned in scale and paged in ad hoc A4 forms.

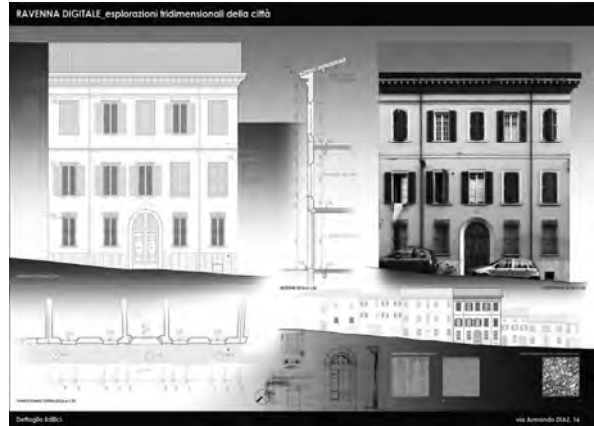


Figure 15: Detail of a façade



Figure 16: Detail of a façade

## 2.3 Visualize and browse the model in Acrobat 3D

Considering the premises, the digital model must be visualized in an easy way, even without particular software, accessible using popular media such as the Web, CD or DVD.

It was chosen to experiment Acrobat 3D version 8. This software seemed the most convincing among every other conversion software and formats.

Acrobat 3D can utilize a variety of file formats, including many types of 3D models. It allows to convert preserving the original file's structure. The number of polygons can be reduced, to remove small objects and duplicate parts, and to decrease the overall file size.

Acrobat 3D 8.1 stores 3D data as either PRC or U3D (Universal 3D) format. U3D is an open standard format adopted by ECMA International used primarily for visualization and publishing purposes. U3D settings are available for most CAD files created in digital content creation applications. These settings are also available for most CAD files created in mechanical engineering applications. Benefits of U3D format: Supports animations; editable in Adobe Acrobat 3D Toolkit.

In conclusion, the choice of Acrobat 3D meets the following requisites:

- wide opportunity to control the parameters of conversion intervening on quality/dimension of files;
- conversion of files in large formats;

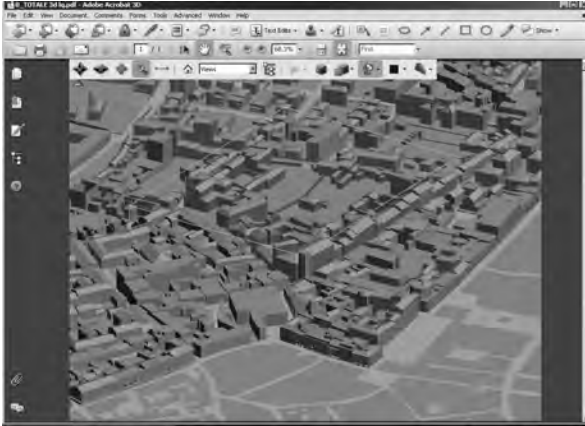


Figure 17: Screenshot 3D model in Acrobat 3D

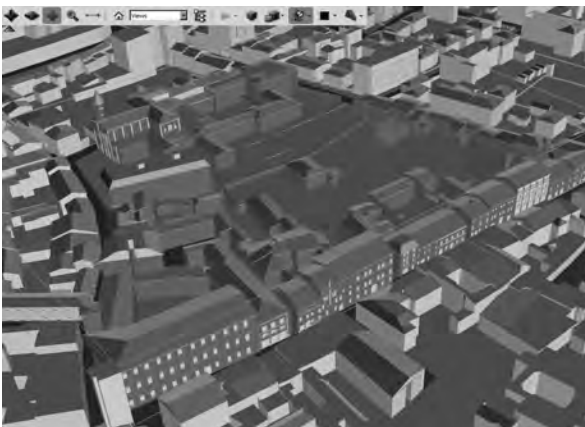


Figure 18: Screenshot 3D model in Acrobat 3D

- conservation of the original file's structure (layer hierarchy...) explored through the "model tree", in particular, in addition to layer, managed objects can be selected and displayed as "isolated" compared to the context.
- possibility of inclusion of PDF files in other applications, eg.: MS Office;
- navigation and exploration of the model and ease to recall assigned views;
- many ways for rendering the model while adjusting lighting. The model rendering modes include combinations of factors that affect the appearance of the 3D object. The illustration below shows a simple object rendered in each of the available modes.
- possibility of "cutting" the model. Displaying a cross section of a 3D model is like cutting it in half and looking inside. Use the Cross Section Controls dialog box to adjust the alignment, offset, and tilt of the cutting plane.
- measurement of the objects displayed;

Among the various features, the most significant one in this context is the ability to convert large assemblies, which other kind of formats and software was unable to manage and convert.

Finally, the possibility to easily connect objects of the model to external applications makes possible to explore the model together with the data associated to the model itself.

### 3. CONCLUSIONS

The results obtained in this work constitute a preliminary research phase; the analysis of this framework allows to program future activities, defining methods and necessary tools. The first step showed the necessity to attach textures to the reconstructed buildings, and to highlight the infrastructural components of the city too. Moreover, it should be recommended to widen the field of research to other parts of the town which are meaningful for the town itself. These include the relationship between the city and the sea, through the city harbour, the channels, the port and also the archaeological sites of the so-called "Lower City".

A preliminary close look concerns the modelling of infrastructural systems such as roads and water related systems, including those that are now invisible (e.g. urban navigable channels, channels generally), underlining the principal characteristics of the model, its geometric dimensions, flows of traffic, etc.

Closely linked to this theme is the analysis of urban knots (squares, axes, large architectural complexes...), and urban historical and future transformations. The visualization of these phenomena using a 3D model, through opportune data filtering, allows turning the model into an effective tool for simulating interventions and substituting buildings. Moreover, the characteristic of the representation of the keys sceneries of the city, the gardens, the green spaces, the paved surfaces and the asphalted ones, are to be objects of further analysis.

#### 3.1 Technical developments

The construction of the model will be subject, at an operational level, of the following technical development:

- completion of the model of the historic center;
- enlargement to significant parts of the city (port, archaeological sites...);
- evolution of the coding of the 3D elements, with a partial redefinition of the organization of the layers, to improve the representation of the objects according to different levels of detail (LOD); the recalibration must also consider some specificities in managing elements of the 3D PDF;
- redefinition, through a more precise sampling, of the casuistry of the 3D elements, in order to get an improved uniformity in modelling complex elements;
- identification of elements whose modelling and rendering can become particularly computationally expensive and definition of specific guidelines supporting operators;
- improving technical arrangements for connecting external database object model \*.PDF and design of specific search filters and related systems highlighting objects graphs (eg.: note or file attachments to objects graphics, automation of Relation ...);
- defining a TAG dictionary to link to the graphic elements, to query the model and visualize only the items which are relevant to the search;
- creation of a navigational and query-based interface and to specify visible and utilizable models in Acrobat Reader;
- animations and explorations.





Figure 19: Digital "Mosaic"

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#### 5. ACKNOWLEDGEMENTS

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## **DIGITAL DELPHI: THE 3D VIRTUAL RECONSTRUCTION OF THE HELLENISTIC PLUNGE BATH AT DELPHI**

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**KEY WORDS:** Archaeology, 3D Modeling, Virtual Reconstructions, Spatial Analysis, Archaeometric

### **ABSTRACT:**

Delphi was inhabited from the Mycenaean period onwards, and beginning in the 6th century BCE its famous sanctuary gained a position of unparalleled importance in Greek political and religious life. Today, the monuments at the site are in varying states of preservation with the best preserved being the restored Treasury of the Athenians and the theater. Since the late 19th century, excavations at Delphi have been undertaken by the French School. *Ashes2Art* is an ongoing collaboration between Coastal Carolina University and Arkansas State University in which undergraduate students work with faculty to create archaeometric models of ancient monuments which are then vetted by a panel of experts and posted online. The project directors of *Ashes2Art* work with specialists in each field, including excavation directors, to ensure the sites are accurately restored. Viewers can then navigate through the virtual reconstructions using open-source software. Since 2007 the project has been focusing on the Greek sanctuary of Delphi, and several areas of the sanctuary are under investigation including the Marmoria and the gymnasium to the west. In this paper I will discuss the value of *Ashes2Art* as a pedagogical model, and then will demonstrate how the 3D computer model of the Greek bath at Delphi provides us with new information about the bath and also allows for a new interpretation of the way that space functioned in the Greek gymnasium in antiquity.

### **1. INTRODUCTION**

Delphi was inhabited from the Mycenaean period onwards, and from the 6th century BCE onwards its famous sanctuary gained an unparalleled level of importance in Greek political and religious life. Today, the monuments at the site are in varying states of preservation with the best preserved being the restored Treasury of the Athenians and the theater. Since the late 19th century, excavations at Delphi have been undertaken by the French School. In early 2007 Coastal Carolina University and Arkansas State University joined together in a collaboration called *Ashes2Art*, focusing on the Greek sanctuary at Delphi. In this paper I will discuss the value of *Ashes2Art* as a pedagogical model, and then will demonstrate how the 3D computer model of the Greek bath at Delphi not only provides us with new information about the bath, but also allows for a new interpretation of the way that space functioned in the Greek gymnasium in antiquity.

### **2. DIGITAL MODELS**

In his *Description of Greece* the 2<sup>nd</sup> century CE travel-writer Pausanias describes various monuments at Delphi and places the sanctuary within its topographic context, describing the buildings that were still preserved in the 2<sup>nd</sup> century and recording the mythical history of Delphi and votive offerings given to the oracular god Apollo. In his description of the entrance into the sanctuary and the path along which the ancient visitor would have traveled, Pausanias notes, “When you enter the city you see temples in a row. The first of them was in ruins, and the one next to it had neither images nor statues. The third had statues of a few Roman emperors; the fourth is called the temple of Athena Forethought. Of its two images the one in the fore-temple is a votive offering of the Massiliots, and is larger than the one inside the temple.” (Paus.10.8.6)

Despite Pausanias’ impressions of the physical monuments, it remains difficult to fully visualize the sanctuary as it once was, and even the best physical models have limitations since the viewer cannot “walk” through the site or engage the space with any sense of proportion or scale. One of the advantages of digitized three-dimensional models is that the modern visitor can do just that. Digital reconstructions allow us to move outside the traditional boundaries of art history, archaeology and other disciplines in the Humanities, considering sight lines (which buildings could be seen from certain areas within the sanctuary), the ways in which space would have functioned in antiquity, and how these buildings would have interacted with one another. Unlike small scale models, which are of tremendous value in their own right but ultimately are fixed and static, virtual reconstructions are dynamic and plastic, allowing for additions to the model as new information surfaces. One of the research outcomes of virtual reconstructions is that the built environment offers access to new types of information about ancient sites, allowing us to engage a diverse set of experimental architectural problems, including lighting, drainage and ventilation reconstructions and engineering issues.

The past decade has witnessed an exponential increase in the creation of three-dimensional models of ancient sites. While these reconstructions are often breathtaking, those types of models have not been without problems. The “reality” suggested by the models can overwhelm the accuracy of the reconstruction and compromise the underlying assumptions of the reconstructive effort (Favro, 2006). Basic problems of proportion, color, scale, and sculptural decoration also pervade many of these projects. Despite the issues inherent in the modeling of ancient buildings, carefully rendered and archaeometric digital reconstructions of various ancient sites are growing in number and complexity.

### 3. ASHES2ART: DELPHI

*Ashes2Art: Virtual Reconstructions of Ancient Monuments* is an innovative, ongoing collaborative concept between Coastal Carolina University and Arkansas State University. In the *Ashes2Art* collaboration, students and faculty at both institutions work together to create virtual reconstructions of Panhellenic sites. The primary focus of *Ashes2Art* is to create accurate digital restorations of various sites and to supplement those models with essays, panoramic images, active sitemaps, extended bibliographies, and a clear and transparent methodology. Although there are several projects that have arisen over the past several years in which students work to create 3D virtual models of monuments, this is the first project that we know of that focuses on undergraduates who conduct the work under the supervision of faculty at both universities. The undergraduates come from a variety of academic disciplines, bringing with them expertise from different areas, and most classes have undergraduates representing a variety of academic majors, including graphic design, art history, art, or computer science. Project directors from both universities then work with specialists from various fields, including excavation directors, to ensure that the monuments are accurately restored. Eventually these results are published online and visitors to the website are able to navigate through the virtual reconstructions using open-source software.

In spring 2007 *Ashes2Art* focused on the Greek sanctuary of Delphi, and several buildings were studied and modeled including the Treasury of the Athenians, the temple of Athena Pronaia (Figure 1), the gymnasium, the xystos (running track), and the Hellenistic plunge bath—which will be discussed here.



Figure 1: Detail of Tholos of Athena Pronaia exterior by Greg Schultz, Coastal Carolina University, illustrating one proposed reconstruction of the roof.

#### 3.1 The Hellenistic plunge bath

That swimming was a central part of Athenian life is suggested by a variety of ancient sources. Herodotus, writing in the 5<sup>th</sup> century BCE attributed the Greek victory at the Battle of Salamis to the swimming skills of the Greeks. (Hdt. 8.89) Plato, writing in the 4<sup>th</sup> century BCE, and Diogenianus Paroemiographus, writing two centuries later, both put swimming on the same level as reading. In *Laws* Plato notes, “These stupid people are called wise although, as the proverb goes, they do not know how to read or to swim.” Diogenianus echoes this, saying “Not knowing how to swim or to write. For the Athenians they learn these skills from childhood.” (Diogenian. 6.56) Pausanias mentions annual “swimming races” held by the Greeks and there are many literary references

to Greeks swimming in the seas and rivers. (Paus. 2.35.1; Hdt. 8.89; Pl. *Resp.* 5.453d; Ar. *Plut.* 656ff; Hom. *Od.* 6.210ff)

The sites of the Panhellenic games all had significant swimming facilities. The rectangular swimming pool at Olympia dates to the mid-5<sup>th</sup> century and is the earliest known swimming pool associated with a gymnasium in Greece. The mid-4<sup>th</sup> century pool at Isthmia is the largest pool of this type in Greece. These large pools would have accommodated the swimming of laps by athletes. Delphi and Nemea had plunge or immersion baths in which athletes would have bathed. The bath could also have been incorporated into an exercise regime. The space constraints at Delphi might have played a role in determining the type of bath used in this context, since both types of baths are found in gymnasia.

The Hellenistic circular plunge bath at Delphi, dating to the last quarter of the 4<sup>th</sup> century BCE, is located in the central court of the gymnasium, to the northwest of the palaestra. (Figure 2) The limestone bath had an interior diameter of 9.7 m. and was ca. 1.9 m. deep. The bath, in its current state, is formed by three slightly irregular superimposed rings of limestone, but in its original state the bath included a fourth course. The courses descend at angles providing seats or steps for the bathers. While no floor for the bath was recovered during excavation, the floor was most probably paved and covered with layers of fine waterproof cement.



Figure 2: Greek plunge bath at Delphi. Photograph by A. Gill.

Ten marble basins are aligned in a row under the retaining wall of the upper terrace of the gymnasium to the east of the pool, in an open-air washing area. The arrangement of the basins in close proximity to the bath is a popular Hellenistic configuration. The basins would have been filled with Castalian spring water from a channel running behind the wall. Water then flowed into each basin, perhaps through a lion-headed spout placed in the wall above each chest-high basin. (Figure 3)



Figure 3: Detail of lion-headed spout by David Mitchell, Arkansas State University.

Cuttings in the ends of each adjoining basin allowed water to have flowed between the basins and eventually poured out onto the ground. This arrangement would have allowed athletes to wash themselves in basins that would constantly be filled with clear running water. After emptying onto the ground, water would have been collected in a central water channel, traveling ca. three meters to the pool and emptying into water channels running along the top course of the bath, some sections of which are still preserved. (Figure 4) This arrangement does not seem ideal since water used for basin washing would have been re-used in the pool. This water delivery system has also been problematic since it does not allow for an easy way to have water flow out of the pool.



Figure 4: Greek plunge bath at Delphi. Detail of water channel. Photograph by A. Gill.

There is no evidence to suggest that the bath ever supported a roof of any kind. While covered bathing developed in Greece in the late 5<sup>th</sup> to early 4<sup>th</sup> centuries BCE, the Delphi bath is one of the latest examples of a bath in the open air. (Ginouvé 129, n. 7) The uncovered bath is also consistent with other baths of this type in Greece associated with athletic contests, including the Greek baths at Isthmia and Olympia, both of which are unroofed.

The reconstruction of the plunge bath and wash basins was based on the excavation reports, and the bath was modeled as precisely as possible. (Figure 5) Of particular interest in the modeling of this building was the consideration of the water delivery system for the bath. Once the model was constructed, the water flow into the bath was clear. One of the most interesting aspects of the three-dimensional reconstruction of

the bath was the clarification of the way that the pool would have been emptied—something that could not be easily seen from the physical evidence alone. Once the bath was constructed, a comparison of the bath to the plan of the bath from the excavation record allowed us to align a drainage area to the retaining wall to the south of the bath. A small hole in the lowest course of the bath would have connected to a channel which would have carried water away from the bath, allowing the water to have been continuously circulating through the bath. This arrangement would not only have allowed for a constant circulation of water, but it would also have kept the pool very cool for athletes wanting to bathe. It should be noted that this constant circulation of water, while simple in many ways, represented a technological advancement in immersion baths, since in earlier periods bathers would have had to have basins filled and emptied by hand. It should be noted here that the observation about the water delivery system associated with this bath could not have been done using traditional methods. Instead, it was only with the three-dimensional model that we were able to “see” how the bath functioned in its original state.

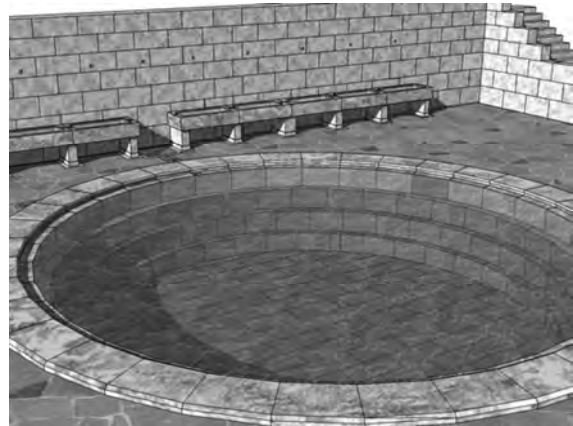


Figure 5: Detail of plunge bath at Delphi by Richard Taylor, Arkansas State University.

The creation of a 3D model of the plunge bath allows for an in-depth spatial analysis of the bath, and the relationship between the bath and the areas surrounding it. One of the interesting areas of inquiry is movement between this area and the adjoining ones, allowing for some interesting observations about the uses of space in antiquity.

#### 4. CONCLUDING REMARKS

The 3D virtual reconstruction of the Greek bath at Delphi not only provides us with additional information about how the bath functioned in antiquity, but it also allows for a spatial analysis that is critical to our understanding of this structure. The reconstruction allows us to speculate on issues involving usage, views, lighting, and the place of the bath within the associated complex. The *Ashes2Art: Digital Delphi* project adds to our understanding of the site, and provides us with a unique view into how this space was used in antiquity.

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## 6. ACKNOWLEDGMENTS

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**THE RIVER AND THE DESERT  
 MULTI MEDIA AS STRATEGY TO EXPAND A PUBLIC SPACE**

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**KEY WORDS:** Virtual, Interactive, Public Realm, Landscape, Architecture, Cognition, Digital Media

**ABSTRACT:**

The Wachau is a riverine landscape, dedicated UNESCO World heritage that is threatened by floods caused from global warming. To protect the villages from the flood a reconstruction of the riverbank is necessary. Spitz is the second town in the Wachau valley that is developing a plan to rebuild its riverbank, a promenade that lost its meaning from the early seventies as a popular public space. This paper suggests a strategy to rethink the promenade as a public space with the intension to preserve, protect but at the same time expand the public space of the promenade. In order to expand this space a new spatial construct will be developed by superimposing a virtual space with the real physical space of the promenade. This intervention will allow to re experience the riverine landscape by intensifying our perception of that unique place.

**1. INTRODUCTION**

**1.1 High Water**

The Wachau was declared part of the UNESCO World heritage in 2000 as an outstanding example of a riverine landscape bordered by mountains in which material evidence of its long historical evolution has survived to a remarkable degree.



Figure 1: View of the existing promenade at Spitz

Increasing floods that are a consequence of global climate change threaten the area and make technical interventions that protect the area necessary. One town in the Wachau valley, Krems already built a dam in combination with a wall that can be raised in case of a flood.

In Spitz, another small town the installation of a mobile flood protection system is discussed. The installation of the foundation wall of this flood protection system will require the reconstruction of the entire promenade along the riverbank. This effort will be used to rethink the public realm of the promenade programmatically.

**1.2 Migration**

With almost 2,000 inhabitants Spitz is a small town that remained its medieval urban structure. The majority of the population is involved in the local vine culture. Spitz also remains a destination point for tourists that come over the weekend for recreation.

In the seventies the town lost its status of being the centre for the local wood industry and its role as the government administrative centre of the canton. Beside the increasing flood these are the two main factors that reinforce a migration of the population. In the past the riverbank was popular as a promenade for tourists as well as residents. The number of tourists as well as the number of residents using the promenade has decreased since.

**1.3 A New Meaning**

Today new museums that are close by are the new attractions that reactivated other public spaces of the town. The promenade has been left out of this development. Art initiatives such as the Kunstmeile Krems, a new museum built 2001 and a relatively new university campus that opened 2005 have put the riverfront in a different context. Therefore a strategy will be suggested to integrate the promenade with its new environment programmatically as a public space that relates to contemporary art and technology and simultaneously preserves the existing cultural heritage

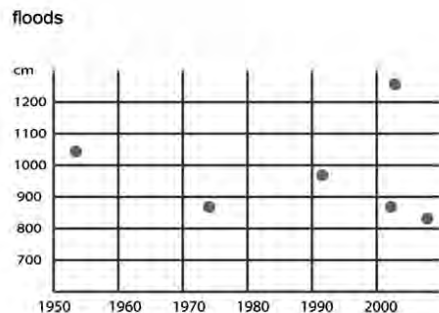


Figure 2: Floods in Spitz over the past 50 years

An increasing number of floods in the past years, e.g. Figure 2 can be related to a shrinking population, e.g. Figure 3. To keep the population and to protect the landscape it is important not only to protect the town from the flood but also to rethink the meaning of the town and its public spaces.

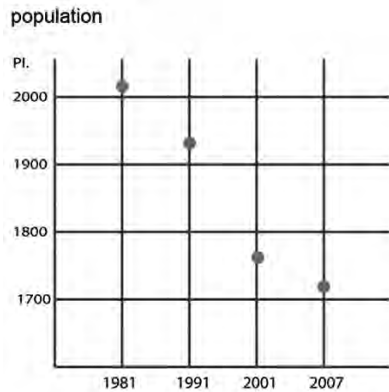


Figure 3: Population of Spitz from 1981 - 2007

## 2. DIGITAL MEDIA

Digital media has changed the space we occupy daily. It has over the last two decades completely changed our social space and other spaces that we operate in such as the market space, the space of education or the space of science. The physical space of architecture in contrast still resists the dialogue with the space that is defined by digital media. Also architecture tends to suggest a more dynamic physical space it is still stable and not modifiable or flexible or open to digital media as suggested.

Similar to Baroque frescos that expanded the space of the Renaissance it is suggested here that digital media can be used to expand the physical space of architecture. As strategy virtual spaces that exist in the second reality of the Internet will be translated and appropriated in order to establish an intense spatial dialog between the physical and the virtual realm. From this dialog a Flux Space, a new spatial condition will emerge that operates between the physical and virtual space. This Flux Space is an expanded physical reality that has the potential to intensify our perception and experience of the physical space that is already familiar to us.

A prototype of a Flux Space has been tested in an installation at the Arthur Ross Gallery in New York last year. This installation will be used conceptually to construct a virtual space at the scale of a large public space of the riverfront in Spitz. The project is suggesting the integration of an infrastructure for Digital Media installations along a 650m promenade at the Danube-river. It will show how a Flux Space can be used to re activate an existing public space by redefining its principles and intensifying our perception and experience of the promenade.

## 3. DIGITAL BAROQUE

The Abbey of Melk, a massive baroque Benedictine monastery is 19 km from Spitz. One of its main spaces, the Marbell Hall will was used as an initial starting point for Flux Space. The architecture from Jacob Prandtauer and the frescos from Johann Michael Rottmayr, both from the time between 1702 and 1736, are joined in an aesthetic unity – Gesamtkunstwerk. Giordano Bruno's idea that the universe was not a dome rather an infinite space was not just accepted here in the early

seventeenth century but also fully translated in a space that seems to continue into the boundless depth of another dimension. A dramatic illusion is generated by very precisely calculated perspectives and rendering techniques to extend the space into a different reality.

Giordano Brunos concept of an infinite universe informs architecture. A ceiling is not just a ceiling anymore, instead becomes a possible opening into another reality. Each architectural element is extended beyond its function. The space of the Renaissance that was dominated by balance and symmetry has been completely de-stabilized and became a space that is dominated by the effects of an infinite space of movement and action. The space that in the Renaissance was a structural closed entity has in the Baroque lost its boundaries - form has been dissolved by painting. Heinrich Wölfflin talked about a new conception of space, a space directed towards infinity.



Figure 4: Frescos by Johann Michael Rottmayr

The digital virtual worlds that we navigate in are usually flattened to a screen. Similar to the dialogue between painting and architecture digital media might enter a new form of dialogue with our physical space - a Digital Baroque, a space that is extended through Digital Media.

## 4. INTENSIFYING PERCEPTION

We are able to break down our environment into digital data. This digital world is according to Vilem Flusser a sand of data, a "desert". Understanding the world as a desert of data has an enormous potential since the data or grain of this desert can be reorganized or reinterpreted into endless new virtual realities.

Digital media, with the capacity to master complexity, has permitted an unprecedented ability to reinterpret our environment. Relating and integrating these virtual realities with a physical space by superimposing the two will generate a new reality. Since this virtual plus real construct is continuously creating new realities it has the potential to impact our cognitive framework by intensifying our perception of our physical reality.

According to Ernst von Glaserfeld, every new reality, in this case the realities that emerge from the process of relating a virtual interpretation with its original physical space has the

potential to destabilize our cognitive framework and therefore the potential to expand our cognitive construct.

Using this concept of instability in order to expand our cognitive framework there are two challenges or problems that we have to overcome: The first problem relates to our own interface to our environment that as we know from Kant constitutes a break. In addition to that the complexity of our environment is highly reduced by the limited capacity of our sensor's receptors. The second problem relates to the way our brain functions as a self-referential network. As described by Humberto Maturana, the brain is an autonomous system that maps through an environment back onto itself. We are therefore constantly trying to match other exterior realities with our own, aiming for consensus.

## 5. FLUX SPACE

A virtual space can serve as interface of our physical space by continuously stirring the grain of data or reinterpreting information that is extracted from it. Allowing for this mediation and communication of a virtual space with a physical space by superimposing them generates a spatial experience that continually engages us in new interpretations of the original space. This space that is extended through digital media such as the Baroque space is extended through painting will be called Flux Space, a space that has the potential to advance our cognitive framework by continuously generating new conflicts with our own reality.

The interpretations that are generated by continuously stirring and processing of information require new kind of instruments, instruments that can serve as interfaces and that allow a communication or mediation between data and data carrier. The instruments proposed here are different forms of digital media that will be defined as systems that have their own rules and boundaries. Manipulating the rules of these digital media systems will produce an endless number of new realities.

A Flux Space is continually reading, interpreting and processing information of a space and continuously feeding this information back into the real space. In order to reinterpret complex information digitally Max/MSP was used as a tool to inform a virtual model of the existing space that has the capacity to interpret and process information in real time.



Figure 5: Photograph of the Installation

Our goal is to allow new realities to emerge from this interpretation of data collected from a specific site using digital media. Since a transposition of information is challenged over

representation or translation of information the possibilities of new realities that can be constructed by digital media are endless.

This idea of a Flux Space has been tested as an installation in the Arthur Ross Gallery in New York last year. A gallery space was reconstructed as a virtual model in Maya, a 3D modelling software. Four high-resolution video projectors were used to project the virtual model back into the real space. Eighty percent of the entire wall, floor and ceiling surface were covered by the projection, e.g. Figure 6. After overlaying the real space with the virtual model of the same space, the spectator occupied the virtual space simultaneously as he occupied the real space.

Installation setup

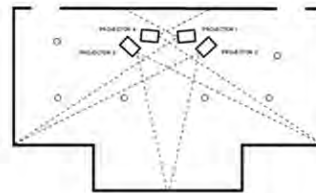


Figure 6: Installation setup for Flux Space

In a second step the information of the reconstructed virtual model such as geometrical principles used in order to reconstruct the space, texture maps that were used to reproduce lighting effects was related with information that was produced by the user such as movement or sound that was recorded in the real space.

In order to couple both sets of information a set of rule had to be invented: For instance the movement of the visitor that was recorded through sensors that triggered the wall to bend. Coupling this information in real time allowed the visitor to interact with the spatial construct.

In that way a continuous feedback loop between the visitor and the spatial construct was generated. The visitor and the space that informed each other were set into a constant flux of interaction.

This Flux Space was then extended further. Text and other information were introduced to allow a communication with spaces beyond the gallery. Since the rules that were invented to allow for the Real Space – Virtual Space – Visitor communication loop were based on digital, abstract information an infinite sets of rules could be invented to generate new spatial qualities and effects.

The space of the gallery continuously changed according to the movement and actions of the occupant. Visual information from the real and virtual space was blurred and the perception of the gallery space redefined.

## 6. DIGITAL WACHAU

The planning of the flood protection system in Spitz started in May 2006. In August 2007 Gernot Riether was invited by the mayor of Spitz, Dr. Hannes Hirtzberger, to rethink the



promenade as an urban space and find strategies to relate that space to existing public spaces and art projects such as the installation "Camera Obscura" by Olafur Eliasson on the Spitz – Arnsdorf ferry.



Figure 7: Site plan of the promenade

The first presentation of a site specific Flux Space to the government was in August 2007. Currently the project is in a design development phase. By November 2008 it will be fully integrated into the master plan of the flood protection system. The start of the realization of the master plan is scheduled for early 2009, completion by the end of 2010 / early 2011.

The budget for the realization of the entire master plan is EURO 17 million. The project is sponsored by the European Union, the Austrian government and the county government. Five to six percent of the budget will refer to Flux Space as well as other related design projects along the 1.6 km strip.

The project is suggesting the integration of a multi media infrastructure that supports the generation of different media installation or virtual realities that can be superimposed with the space of the promenade. Flux Space will occupy a 650m section of the entire 1.6 km long riverfront that belongs to the master plan.

The concept of a Flux Space installation will in that way be applied to a much larger project of a public space of a promenade, the riverfront of Spitz in the Wachau valley.

A media infrastructure will allow for a virtual space that will be superimposed with the existing environment. Different media artists will be able to use that infrastructure as a foundation for different digital art projects and will be able to generate different spatial constructs. From these spatial constructs new spatial qualities will emerge that are not only constructed by the individual artists but also continuously manipulated by the public that will interact within the different constructs. In that way the full potential of Digital Media can be explored in multiple ways to extend the public space.

Similar to the installation Flux Space the real space will be used to inform a new virtual space that will be superimposed with a real space. To interpret the site of the riverbank as a digital space, methods of recording and displaying information were found and rules invented using the possibilities of different digital media, to explore its full potential to interpret information in multiple ways. A continuously reconfiguring of digital media will allow us to interact and communicate with the site of the riverfront in continuously new ways.

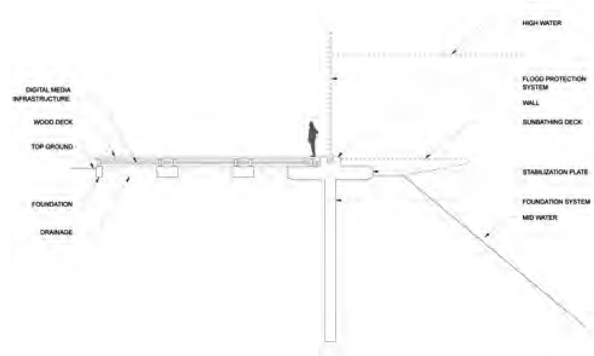


Figure 8: Section of the promenade

At specific access points along the promenade data will be recorded, e.g. Figure 9. This data might be originated from the user that might leave behind a digital trace. Data might also be recorded from the natural environment such as sound light or wind speed. Virtual spaces of sound and visual effects will be constructed by interpreting the collected data. This constructed virtual space will be superimposed with the real space of the promenade. The resulting spatial condition will allow for a new understanding, reading and interpreting of the landscape that might intensify our perception of the Wachau landscape.

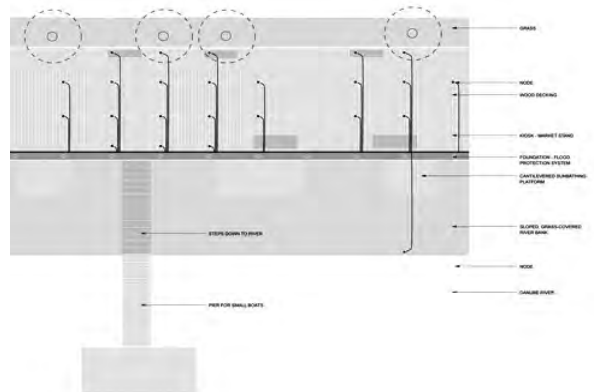


Figure 9: Plan of installation layout



Figure 10: Rendering of the new promenade

In order to integrate the infrastructure to allow for a changing virtual space and at the same time preserving the existing appearance of the landscape only the surface of the promenade will be exchanged into a more flexible media-surface. This surface will function as an infrastructure of the virtual space.

An interstitial space will be created by raising the floor surface of the promenade to be flush with the foundation wall of the

flood protection system, e.g. Figure 8. This interstitial space will be equipped with an infrastructure that consists of a network of nodes or access points. The nodes will be articulated as small, networked containers that can be equipped with recording or displaying devices. Conceptually similar to the flood protection system the media surface will be another foundation in this case a foundation or infrastructure for different virtual spaces.

Collected data might be reordered and reorganized and reconstructed into new virtual spaces that will be superimposed with the real space of the promenade. The resulting spatial condition will place the visitor in a “Physical Space - Virtual Space - Occupant” feedback loop that might trigger a new form of interaction within an existing space, a new understanding, reading and interpretation of that space - an interaction that might also intensify our perception of that space.

**6.1 Memory Space:**

Sensors will be used to record the visitor’s movement. During the night the system of sensors will be coupled to the lighting of the promenade.

The promenade will only light up at areas occupied. In another scenario the movements of the occupants can be recorded and replayed at a later time by the use of lighting or sound effects. The abstraction of the occupant’s movement will generate a new space, a space of memory that will invite new occupants to interact with.



Figure 11: Layout for “Memory Space”

**6.2 Fragmented Space:**

The sound of water will be recorded close to the water surface and replayed at a location of the promenade that is far away from the water. On other locations of the promenade a conversation might be recorded that will be replayed on more remote locations of the space. Using microphones to record and isolate the sound of specific locations the public space of the promenade will be broken up into fragments. These fragments will be rearranged into new sound spaces. The possibilities of generating new sound spaces by rearranging the fragments are endless. The visitor can search for these new emerging spaces, engage with them and continuously re-experience the spatial interpretations of the promenade.



Figure 12: Layout for “Fragmented Space”

**6.3 Conversation space:**

A system of microphones and speakers can record one voice on one place and replay it on another place of the promenade. The integration of this communication infrastructure will allow for a new communication space that will have the potential to intensify the existing communication space of the promenade, a space that will be characterized by anonymity and blurred boundaries of public and private spaces. Thereby a space similar to the virtual space of the Internet will be constructed as a physical space.

Different nodes of the promenade will also be accessible from outside. Messages can be sent to specific nodes by e-mail. In that way the promenade thereby would be tied into the larger communication space of the World Wide Web and might become a new platform for a social network that does not just exist in the Internet but will simultaneously in an intense spatial relationship with the physical space of the promenade.



Figure 13: Layout for “Conversation Space”

**7. CONCLUSION**

Digital processing of information that is collected from the riverfront will allow us to generate an endless amount of new interpretations of the existing space of the promenade, such as interpretations of people’s movement that will be interpreted as sound effects for instance. Each interpretation will inform a new virtual space, a new reality.

In that way Digital Media is used to mediate or communicate between the user and the environment. Real space, virtual space and user are connected in a continuous feedback loop system. Through these loops new realities will be produced that will have the potential to destabilize our cognitive framework.

Since we will continuously be confronted with new interpretations the promenade that will be turned into a Flux Space will have the potential to intensify our perception and understanding of an existing environment and our relation to this specific place.

The virtual realities are not projected on a screen or in a gallery anymore they are in an intense dialog with the space of the promenade. Similar to Baroque frescos by Johann Michael Rottmayr Digital Media is an extension of a space, a space that can also be changed and manipulated in an infinite number of ways. It is a spatial construct that will influence the way we use a space, move through it and interact with it.

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## 9. ACKNOWLEDGEMENTS

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Gernot Riether with Ruth Ron, Atsunobu Maeda and Renate Weissenboeck

### Riverfront Spitz:

Gernot Riether Studio, Project Team Riverfront Spitz an der Donau: Sal Lalani, Hanyun Huang

## MEMORY OF THE SILK ROAD-THE DIGITAL SILK ROAD PROJECT-

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**KEY WORDS:** Digital Archive, Silk Road, Rare book, 3Dimensional Digital Reconstruction, Virtual Museum, Image DB

### ABSTRACT:

The Digital Silk Road (DSR) Project is an international research project conducted at National Institute of Informatics (NII) of Japan. The project aims to create a digital archive of the cultural heritage related to the Silk Road, and to establish a new style of Silk Road study for the 21st century. We present the on going project in this paper, mentioning the project organization, concept, and implementation by reviewing our achievements through demonstrations. This is a multi disciplinary research project led by NII in cooperation with relevant organizations and researchers. The major achievements of the DSR project are: 1) Digital archiving of the Toyo Bunko's Rare Books related to the Silk Road. 2) 3D-VR restoration of the Citadel of Bam destroyed by the earthquake. 3) Digitizing some old maps of the Silk Road drawn by M.A.Stein about 100 years ago. By browsing old maps on Google Earth, we created an error distribution of maps by comparing old maps with satellite images on Google Earth. 4) A DSR Imaginary Museum portal that provides a digital Library, Museum, Cinema and Panorama of the Silk Road. Silk Road route map and chronological map were developed to submit and share the multimedia contents of the Silk Road images and videos in public and group domains.

### 1. INTRODUCTION

Nowadays, historical, cultural, and natural heritage is on the verge of disappearing due to the passage of time, wars, disasters, and other factors. However, information technology has provided us with opportunities for recording, archiving, and disseminating digitized information on cultural resources, creating space for intercultural dialogues, and new cultural expressions. National Institute of Informatics started the Digital Silk Roads (Shortly DSR) project in 2001 in cooperation with United Nations Educational, Scientific, and Cultural Organization (UNESCO). The project aims to create a digital archive of the cultural heritage in the Silk Road region, and establish a network collaboration system by linking advanced information technology with cultural sciences. (Ono et al. 2002, Ono et al. 2004). The purpose of this paper is to report on the progress of the "Digital Silk Road" project by referring to our ongoing subjects and past achievements.

### 2. DIGITAL SILK ROAD PROJECT

#### 2.1 Background

The Silk Road is the name for the trade route where a vast amount of commodities and cultural activities were exchanged in the Eastern and Western areas of Eurasia Continent. The German geographer Ferdinand von Richthofen was the first person to use the term "Seidenstrasse" (the German word for Silk Road) to describe the route connecting China, West Turkistan, and North western India. Another German scholar of Eastern Studies, Albert Hermann, called the route from China through Syria and Rome, the Silk Road. The Silk Road is presently interpreted in a very broad sense, and it was a network that not only traded silk but many other exchanges occurred through cultural activities. Three trade routes, the Step Road, the Oasis Road and Ocean Road, were also referred to as the Silk Road because of the area's natural features. Invaluable

cultural and natural heritage still remaining in the Silk Road region are certainly a significant witness to human history and should be preserved and passed on to future generations as a great common asset to humanity. The DSR project tries to link advanced information technology with cultural studies in order to further enhance interest in the precious cultural assets along the Silk Road.

#### 2.2 Objectives of DSR Project

The project seeks to establish a new approach to Silk Road studies, featuring the fusion of cultural sciences and information technology through digital archiving and network collaboration. The objectives of the Digital Silk Road project are to create a digital archive of the geographically dispersed Silk Road heritage and develop a system to facilitate the use of the digital archive, featuring the integration of advanced information technology and cultural themes in distributed environments. This means we want to conserve the Silk Road heritage in digital form and make it available to for retrieval and sharing world-wide through Internet. That is to say we want to lay the foundation for a new concept for Silk Road studies under the name of Digital Silk Road and to create a Virtual Museum for the Silk Road. Following this line of thought, the project started to digitize rare books related to the Silk Road that are in Toyo Bunko's possession and those held by some other organizations and individuals, and digitize them to develop a information infrastructure aimed at fully utilizing such contents. (Ono et al. 2005).

In addition, the Citadel of Bam destroyed by the earthquake was digitally reconstructed using a 3D CG technique. Based on the results of these attempts, the project will expand its scope to include other major Silk Road cultural heritage with a view of completing the Digital Silk Road Museum in the future. (<http://dsr.nii.ac.jp>)

### 2.3 Project organization

The project is mainly organized by NII researchers from multi-disciplinary fields, such as history, archaeology, architecture and information technology. In cooperation with relevant organizations, the project is led by NII and a number of scholars and experts from various disciplines who have taken an interest in digitally archiving Silk Road heritage (Ono et al. 2005). Toyo Bunko has many books, manuscripts, and maps related to the Silk Road. In order to make a digitization of the Toyo Bunko's rare books, we established a close relationship with Toyo Bunko and have received Kaken fund from the Japan Society for the Promotion of Science(JSPS) related to DB publication for the past five years. Research teams at Tsinghua University as well as from Beijing University in China are also our partners. We hold a DSR workshop every year in Beijing. A 3D reconstitution of the Bam heritage is being conducted under the leadership of NII in cooperation with Iranian Cultural Heritage and Tourism Organization (ICHTO). Waseda University, the University of Tehran, and Espace Virtuel de Conception Architecturale et Urbaine (EVCAU), a laboratory of the Ecole Nationale Supérieure d'Architecture de Paris-Val de Seine (ENSA PVS) in France are our main collaborators. Meetings and workshops for this project were conducted in Tokyo, in Tehran, and in Paris to report and discuss progresses and outcomes.

## 3. DIGITIZATION AND UTILIZATION OF TOYO BUNKO RARE BOOKS

### 3.1 Overview

Books are important resources for dealing the cultural heritage of the Silk Road, because many important cultural heritages were excavated and recorded in books and reports published as the result of expeditions from Europe and other countries in the late 19<sup>th</sup> and early 20<sup>th</sup> century. Some of the heritages can only be seen in books, because the original objects were destroyed and lost after recorded in books. To provide books in a digital form, we created a website called the "Digital Archive of Toyo Bunko Rare Books". The important features of this digital archive are three fold. (<http://dsr.nii.ac.jp/toyobunko/>) (Kitamoto et al. 2006)

1. The collection of academically essential resources.
2. Rich choices of navigation methods including a full text search.
3. Multipurpose utilization of digitized resources.

### 3.2 Academically Essential Resources

This archive is a collaborative project with Toyo Bunko (the Oriental Library), the oldest and largest research library in Japan in the field of Asian studies. From the collection in the library, we carefully selected books in the public domain that have significant academic value. Since 2002, we have digitized 92 volumes (43 titles) from cover to cover (total 19,242 pages). This number seems to be small in comparison to other mass digitization projects such as Google Books, but our collection consists of carefully selected resources that are essential for Silk Road studies. Figure 1 shows a page from a digitized book.

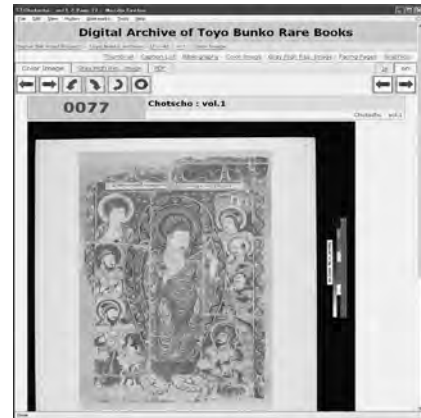


Figure 1: Digitized page

### 3.3 Rich Choices of Navigation Methods

The digital archive of books is not only for preservation and browsing, but also for improving the accessibility to the content of the books. Therefore the website should be equipped with a rich amount of choices of navigation methods across the list of books. Domain experts say that the most basic and convenient method of navigation is the full text search. So, we applied an optical character recognition (OCR) commercial software to obtain the full text of books. However, OCR has a technical limitation and cannot produce perfectly full texts. So, we manually input the more important parts of a text, namely the captions of figures and the table of contents. The OCR and manually inputted texts are then combined to provide a full text search. Figure 2 shows the results of a full text search, where the search word is highlighted on the page.



Figure 2: Full text search

### 3.4 Multipurpose Utilization

Books can be viewed page by page, but the advantage of digitization is in the multipurpose utilization of content to improve accessibility and add value. For this purpose, we wrote essays on the Silk Road with rich links to the highlights of the books first. These essays provide entry points to the books for non-experts with contexts to understand the value and meaning of the cultural heritage. We then created the Senga Silk Road, as shown in Figure 3, which has similar purposes to the essays, but has a different interface. This system offers a database of

cropped images taken from the graphical resources inside books, and lets users create a tour, which is a sequence of images freely collected and ordered by the user. This tour gives, in a participatory manner, a context between images with the subjective interpretation of a user. (Kamida et al. 2007)



Figure 3: Senga Silk Road

#### 4. DIGITAL RECONSTRUCTION AND VIRTUAL REALITY OF UNESCO WORLD HERITAGE IN DANGER, THE CITADEL OF BAM

##### 4.1 Overview

The Citadel of Bam was a historic city with adobe architecture in the Bam region that flourished along the caravan roads such as the Silk Road for the production of cotton and silk. It is a large fortification with a long history of more than 19 centuries of habitation (Mehriar, 2003).

The Citadel and other heritages of the city of Bam were destroyed in an earthquake in 2003, as shown in Figure 4. The site as well as other cultural landscape of Bam region (such as advanced Qanat system) is registered in the list of the world heritage in danger of UNESCO in 2004 (<http://whc.unesco.org/en/list/1208>). Reconstruction of this UNESCO site in danger that covers around 180,000 square meters in area will be a challenge in the physical world. 3D reconstruction and virtual reality of the Citadel of Bam is presented in this chapter. (<http://dsr.nii.ac.jp/bam/>), (Ono et al. 2008)

##### 4.2 First phase of project

**4.2.1 Study of the method and process:** 3D reconstruction of a cultural heritage or of damaged sites can be found in several examples by using photogrammetry, photo modeling, and specially laser scanning. Reconstitution of the Bamian Great Buddha that was generated with Virtuozo digital photogrammetric systems (Gruen et al. 2003), and the Parthenon virtual reality (Stumpf et al. 2003) that was modeled using laser scanning and photogrammetry can be considered as major examples.



Figure 4: Citadel of Bam after 2003 earthquake

In comparison with these cases, our target buildings had mostly been destroyed. Furthermore, 3D reconstruction was necessary for the interior as well as the exterior spaces of several buildings that were made from mud brick and had unusual curves, arches, and other complicated shapes. Moreover there are few detailed images of the buildings that are good enough (photo from different angles, different periods, different resolution and no calibration) for reconstitution by photogrammetry technique (Ioannidis et al. 1996). Therefore, we chose the method of 3D modeling from 2D maps, photos, movies and other resources in a gradual process.

**4.2.2 Case studies and project team:** The most important part of this project is the precise preparation of the 3D models of the buildings of the Citadel by using a variety of heterogeneous data resources. This was a challenge as unfortunately the site was never completely documented before the earthquake and basic data resources were limited. We have separated our project into different phases due to the large number of buildings in the Citadel. The first phase (from 2005 to 2007) was a 3D modelling of major axes of the Citadel, east-west and north-south, and the most important public or private buildings along these axes. Ten buildings with different typologies were selected as shown in Figure 5 (Ono et al. 2008), (Green for Waseda GITI team, Red for UT Razahang team, and Blue for EVCAU team in this figure, copyright of original photo by ICHHTO)

**4.2.3 Virtual Demo:** The finished 3D models of the separate buildings in the first phase were all merged together on a topographic model of the site and were imported inside the Virtual Reality tool (Omega Space) to provide a virtual walk inside the Citadel and its major virtually reconstructed axes, as shown in Figure 6. We presented a demo of the Virtual Reality of the first phase of the site of Bam for experts in September 2006, and then used their comments to improve the quality of the models (Andaroodi et al. 2007)

Moreover, the models were rendered using the texture photos gathered from the site after the earthquake and proper lighting. Then, Quick Time Virtual Reality (QTVR) movies were provided from the most important spots in each building, as well as were rendered snapshots of the model. These two sets of data will soon be accessible over the Internet in the second phase of the project.

##### 4.3 3D modelling process

3D modelling is done on the basis of data provided to NII to be given to different modelling groups. These data mainly consist of 2D drawings surveyed before and after the earthquake, on-site photos (from ICHHTO, from photos gathered as part of DSR website in the memory of Bam or private photos), aerial

photos (from Iranian National Cartography Centre (NCC) and Digital Globe) and photos from movies particularly from Japan Broadcasting Corporation (NHK)), 3D Cartography (from Irano-French 3D Cartographic (IFCA) between CNRS and NCC) and finally oral, textual and sketches from experts. These heterogeneous data were used simultaneously by different 3D modelling groups to develop the models, because basic 2D drawings could not provide all the necessary measurements for the 3D modelling.

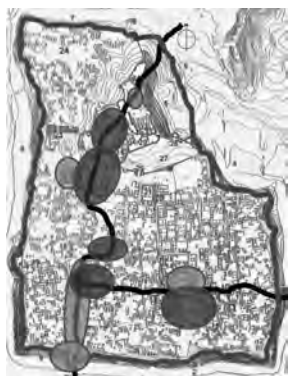


Figure 5: Case studies for first phase of the project on siteplan

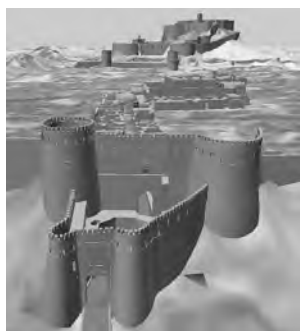


Figure 6: General view Citadel of Bum inside VR tool

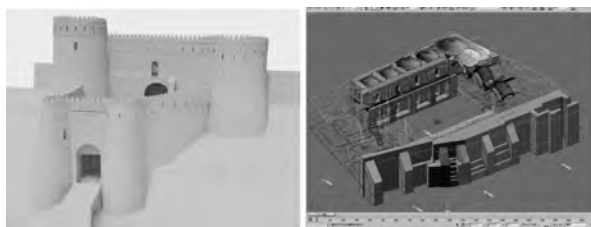


Figure 7: 3D model of entrance and caravanserai

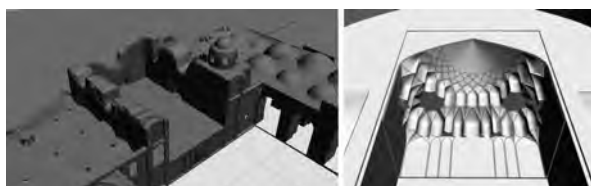


Figure 8: Main iwan of mosque and decorations of Mihrab

As the quality of the 3D models was important for our research to be able to use it as the precise documentation proper for physical restoration, these models were evaluated in three major processes by architectural and domain experts at NII. Evaluation reports of errors were provided for the modelling groups and they completed the models after different modifications (technical and architectural modification) and remodelling were conducted. We have implemented a metadata-based layer-naming strategy to connect similar 3D modelling pieces with their attributes, such as the types of resource that have been used, the names of buildings and the types of architectural components, to ensure the accuracy and semantic access to the components of our 3D models.

#### 4.4 Second phase of project

**3D modelling:** The simultaneous application of such varied and large databases of heterogeneous data directly done by the 3D modellers in the first phase of the project usually leads to confusion about the domain knowledge, errors in the geometry and dimensions, and slow modelling. For solving these problems we developed a CAD-based 3D drawing as a basic resource for the 3D modelling in second phase of the project. In this phase, which began in 2008, is concentrated mainly on the 3D modelling of the Governor District of the Citadel that contains the most important and most complicated parts of it located on top of a hill. The modellers are using only the 3D drawings in this phase of the project for developing the precise models. These 3D drawings being developed by architects and domain experts at NII can unify the heterogeneous data into a single set of data. In addition to the important buildings that must be precisely developed by the CAD-based 3D drawing in a 3ds Max environment, there are some parts (e.g. the second gate of the Citadel and the surrounding walls) with fewer architectural complexity or precision that can be developed through a semi-automatic photogrammetric method for moderately precise 3D modelling. Moreover, a large part of the Citadel, which was the residential districts, was not renovated before the earthquake and did not have a specific shape or form. The main resources of these parts are aerial photos. We try to automatically model these parts in this phase by inspecting the lengths and depths of the building shadows in the aerial photos. Figure 7 shows 3D model of main entrance gate developed by Waseda team and model of caravanserai by the EVCAU team, and Figure 8 shows 3D model of main iwan of mosque and chalk decorations of Mihrab of mosque by UT team.

**4.4.1 Virtual Reality:** We will merge all the completed 3D models into a unified one for the entire Citadel. This process must be done taking into account the level-of-details of the models to make each one using a reasonable number of polygons and file sizes. We plan to later import the VRML file of the complete model in the Omega Space VR tool and provide texture and rendering inside the tool. We will set up a camera in each building so the user can switch between different views. The VR demo will be prepared using stereoscope images from the two cameras on the screen. We will implement a 3D visor Head mounted Device to look at the stereoscope images three dimensionally, and to give the user a real feeling of walking in the site. The virtual walk will be accompanied by narration in each building to present the semantic and historical facts about the site to the users.

**4.4.2 Knowledge-based web site:** We plan to open the outcomes of the first phase of the project, such as the QTVR movies and rendered snapshots of the 3D digital reconstituted

buildings, open over the Internet in order to permanently preserve this lost heritage for access of unlimited users. The outcome of our project has complicated semantics and a simple HTML page can not be used to provide a proper amount of access to the knowledge and the process of each single piece of outputted data. In order to provide a well-structured knowledge-base access to our output data, we have designed an ontology knowledge model for the process and the output of the 3DCG reconstruction of the Citadel of Bam.

This ontology will provide terminology and metadata information for each type of building in the site using a multilingual schema. We have also defined an advanced schema for the process of the project which can be viewed in the website by other researchers and be applied for similar situations. The ontology knowledge model is used to derive a webpage and connect persons, resources, researches, outcomes, and events of our research activity together with multimedia content.

## 5. ANALYSIS OF SILK ROAD MAPS USING GOOGLE EARTH

### 5.1 Overview

Maps are useful tools for representing and analyzing geographical information. Rare books digitized in the Digital Archive of Toyo Bunko Rare Books (Ch. 3) have several maps useful for the study of the Silk Road. To take advantage of these digitized maps, we use Google Earth (GE) as a convenient tool for browsing and analyzing old maps and for integrating information.

### 5.2 Stein Maps

Among several old maps on the Silk Road, the most valuable ones were made by M. A. Stein, who was one of the most important persons in the expeditions of the Silk Road in the beginning of 20<sup>th</sup> century. He went to central Asia four times including his first expedition in 1900, and published a series of reports including the *Serindia* (5 volumes) and *Innermost Asia* (4 volumes) that included surveyed maps.

Although these maps were made about 100 years ago, researchers still regard them as the most reliable maps of the Silk Road. They had problems in using those maps, however. There are only 94 of these maps in *Serindia*, and 47 in *Innermost Asia*, so researchers can only use them sheet by sheet, not as a whole. For this reason, the comprehensive analysis of those maps has not been done, such as evaluating the overall accuracy of the maps.

### 5.3 Using Google Earth for Browsing Stein Maps

We use Google Earth to improve the usability of Stein Maps, for the following reasons. Firstly, it has a built-in mechanism for browsing large maps with a level-of-detail control. Secondly, by having the latest satellite images for background, we can directly compare the old maps with the present layout of Earth to compare the changes and evaluate the accuracy.



Figure 9: Maps on GE

Since the Stein maps were surveyed, georeferencing is made in a straightforward manner by referring to the intersections of the latitudinal and longitudinal lines drawn on the maps. The images of the maps are then organized in Keyhole Markup Language (KML) format with a level-of-detail control. Those maps are now available on our website (<http://dsr.nii.ac.jp/geography/>) and can be viewed like Figure 9. Google Earth drastically improved the usability of old maps. Any parts of the maps can be magnified easily, and all map sheets are connected. Moreover, Stein maps can be easily compared with the current satellite image by changing the opacity of Stein maps. The improvement of usability led to the evaluation of Stein maps for all across Silk Road.

### 5.4 Evaluating Stein Maps

Because ruins and some oasis can be regarded as fixed points since the Stein's survey, we compared the position of those points on the Stein maps and Google Earth, and evaluate the errors of Stein Maps. Figure 10 and 11 shows the idea of comparing points between Stein maps and Google Earth. In the case of Aram-tam temple ruins (Figure 10), the location of the ruin on *Serindia* (cyan) and on *Innermost Asia* (green) is different from the location on Google Earth (yellow). Another example at Mazār-Tāgh (Figure 11) illustrates that the terrain around the ruin looks similar on Stein maps and Google Earth, namely all points are located at the edge of a cliff near the river. Hence we are sure that these locations are the same point on the earth. By making correspondences and regarding the present points as truth, we can evaluate the accuracy of the Stein maps.

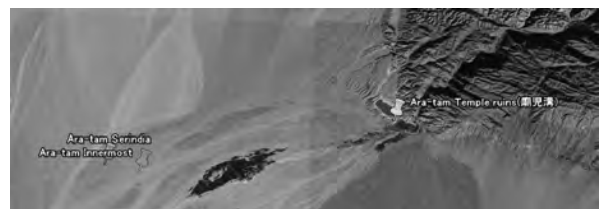


Figure 10: Ara-tam temple ruins



Figure 11: Mazār-Tāgh on GE and Stein Maps



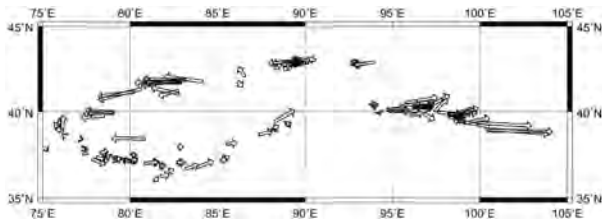


Figure 12: Results of errors in Serindia

Figure 12 illustrates the results of errors in Serindia. The arrows show the errors measured from the present location to the location on the Serindia map. We can see that the errors are longitudinally larger, and increase along the route of Stein’s expedition. There are also areas with a larger number of errors than the others. These errors can be partially explained by surveying the methods employed by Stein, and by the technical limitation that the longitudinal survey was historically much more difficult than that of the latitude. We provided the initial evaluation of the accuracy by area, but this should be improved upon in future work. (Nishimura et al. 2007)

5.5 Digital Maps of Old Beijing

Our experience on Stein maps has been applied to other important old maps. Our latest project on old maps deals with “Complete Map of Peking, Qianlong Period” (1750 drafting), which is the most valuable historical map of Beijing. This is the most detailed map of Beijing from a large-scale architecture point of view, such as from the imperial palace to the individual small houses of ordinary people. Researchers, however, have problems in using those maps due to the large number of sheets (17 volumes and 203 pages), which is a similar problem with the Stein maps. To solve this problem, we digitized the map, and georeferenced the map using Google Earth. Georeferencing was done by picking up about 1,800 control points such as palace, large buildings and intersections that can be regarded as fixed points for 250 years. We then picked up 500 linear features such as walls and roads. They are used for computing the best mathematical transformations between the old map and the present map.

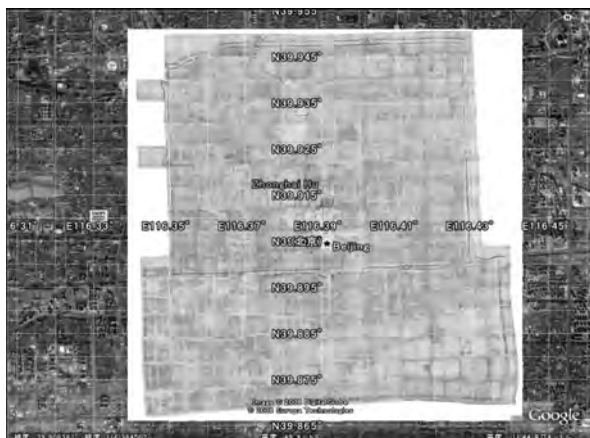


Figure 13: Digital Maps of Old Beijing

The transformation was computed based on the weighted average of nearby points and linear features. Finally the map was released as “Digital Maps of Old Beijing”

(<http://dsr.nii.ac.jp/beijing-maps/>) as shown in Figure 13. This map will be a useful resource for studying the historical evolution of Beijing city, which is now in a drastic change because of a rapid economic growth and the Beijing Olympics.

5.6 Using Google Earth for Integrating Information

Google Earth can also be used for integrating information on maps. The basic way of integrating information is to annotate maps with place marks on the ruins, oasis, and other important places to help researchers and people more conveniently use maps. Another usage of Google Earth for data integration is to add simple 3D models on the maps. Figure 14 shows a simple 3D model of the Bāzāklik Cave (Temple No. 9), which is a Buddhism ruin on the Silk Road. In this example, the images of the wall paintings (murals) were extracted from one of the books in Digital Archive of the Toyo Bunko Rare Books (Ch. 3). Putting this 3D model on Stein maps means the integration of several old books using Google Earth, where the pictures from one book are put on the map made from another book.



Figure 14: 3D model of Bāzāklik Cave (No. 9)



Figure 15: Photographs of the Past and Present

Finally Google Earth can be used for integrating old maps with old photographs. For Digital Maps of Old Beijing (Section 5.5), we released another website, “Photographs of the Past and Present” (<http://dsr.nii.ac.jp/ppp/>) to integrate the map of about 250 years ago with photographs of about 100 years ago. Photographs from the digitized albums that contain photographs taken about 100 years ago were georeferenced, and

photographs of the present can be compared with old photographs on Google Earth. In other words, many kinds of resources that can be digitized from books and many kinds of digital resources that can be captured by us today are all integrated on Google Earth simply by locations.

## 6. DSR IMAGINARY MUSEUM

The DSR Imaginary Museum is a web museum site where the public can access a large amount of multimedia resources in an academic database, such as the “Cultural Online System” and “Digital contents of DSR project”. The DSR Imaginary Museum provides live, user-friendly, and graphically rich cultural information about the Silk Road. (<http://dsr.nii.ac.jp/imdsr/>) (Figure 16).



Figure 16: DSR Imaginary Museum

### 6.1 Museum, Library, Cinema, and Panorama of DSR Imaginary Museum

Bamiyan is a heritage site of Buddhist remains carved on the rock cliffs of the Hindu Kush Mountains that stand 5000 meters high penetrating the middle of Afghanistan. This heritage site is situated in the lush Bamiyan Valley and was constructed between the 5th and 6th centuries AD. The museum site of the DSR Imaginary Museum exhibits photos taken 25 years ago and gives information about the Bamiyan's role in the crossroads of the Eastern and Western culture of the Silk Road.



Figure 17: Panoramic photo view of Bamiyan Valley

The cinema site of DSR Imaginary Museum can show some short videos of the Bamiyan Heritage. The panorama site shows the photos viewed from different angles of the Bamiyan Valley (Figure 17). On the other hand, the library site of the DSR Imaginary Museum exhibits Toyo Bunko's Rare Books, a documentary heritage, manuscripts, and other valuable materials as Digital Library contents.

### 6.2 MAP of DSR Imaginary Museum

As is widely known, the “Silk Road” refers to the numerous trade routes that served to carry silk and other commodities across the Eurasia continent over past centuries. Vast amounts of information concerning science, technology, art and religion have been transferred along the Road, influencing many different peoples and their civilizations in the region. Figure 18 shows the map of the “Silk Road Tour”, which shows the typical view of three main routes of the Silk Road. The Oasis routes run across a series of large deserts and large mountains connecting the Oasis cities. The Steppe route runs north of the Oasis Road in the northern Asia Steppe.

The Maritime Roads gradually expanded from the Mediterranean Sea to the Aegean Sea, Red Sea, Arabian Sea, Persian Sea and the Indian Ocean. Finally it extended all the way to the southern and eastern coastal areas of China and Nara in Japan.



Figure 18: DSR Chronological Maps

The ‘DSR Chronological Map’ is a unique map where everyone can participate to create the Silk Road contents. Contributors can share their information about the Silk Road connecting people and cultures of the west and east from ancient times. Information is collected and categorized by country as currently organized, which is published regularly. Silk Road travellers, Silk Road fans, researchers, scholars, or anyone who owns photos, music, and/or videos of the Silk Road are encouraged to share their information on this site. They can become one of the creators of the ‘DSR Chronological Map’. In order to share the Silk Road resources among specific group members, Group domains are allocated for registered members. Using Group maps, users can submit their multimedia resources to specific sites to exhibit their contents on this map place, comments on the bulletin board, and share contents among the group members.

### 6.3 ASPICO portal

The ASPICO (Advanced Scientific Portal for International COoperation) is a Web-based portal that hosts DSR project members to create a metadata for resources on Silk Road. It supports members to analyze, evaluate, and annotate contents for their Silk Road studies such as iconographical studies of Buddhist paintings at Dunhuang Mogao Grottoes. As an example, we focused on works of Pure Land Buddhism, one of the major sects of Buddhism, and established a database of Sixteen-Contemplation paintings, where sixteen steps of contemplation to visualize Amitabha paradise as a method for rebirth represented in various ways. We arranged drawings and description taken by on-site researchers, then operated

quantitative analysis of the database using ASPICO and got appropriate results (Onishi et al. 2006).

## 7. CONCLUSION

This paper reported on the progress of the Digital Silk Road project, currently being conducted at NII in cooperation with many institutions and researchers over the past seven years. We plan to make the entire system accessible via the Internet, so that users around the world can share and utilize these precious cultural resources. Furthermore, we are working to develop a system to store Silk Road related information and documents together with images and videos so that such information can be referred to quickly and easily.

New technology should be utilized in the future so that maximum benefit can be given to mankind, not only in terms of the economy, but also in terms of enriching our lives and cultures. We believe that utilizing advanced information technology to preserve historic and cultural heritage will certainly serve this goal. Digital archiving technology allows heritage materials and sites thought to be beyond saving to be restored, enabling us to pass on such assets to future generations. The Digital Silk Road project will provide us with a new paradigm of collaboration in the digital age, establishing a route for digital information exchange among the countries along the Silk Road and encouraging the creation of a new cultural form, just as the Silk Road did throughout their history.

The DSR project will enable people to freely explore and experience some of the world's greatest cultural assets without actually visiting them, which had been merely a dream for many centuries. There is no doubt that the DSR project will have a significant impact on the enhancement of cultural diversity around the world.

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