STAG: Smart Tools & Apps for Graphics (2014)
Andrea Giachetti (Editor)

Short papers

Multi-modal digitalization of Cultural Heritage Artifacts

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Abstract

Objects made of different media, paintings, marbles, clay and wooden objects, textiles etc., form the historical collections of most of the middle to medium sized Museums in Italy. This variety poses difficult challenges to these institutions when they face the digitalization of part of their patrimony. This paper provides a report of an ongoing inter-disciplinary experimental program for a digitalization effort to be carried out by one of such institution. Through the discussion of the digitalization of different objects obtained with the use and integration of different techniques we illustrate some of the lessons learned in transferring to the final intended users the graphical tools and the know-how previously acquired in a research laboratory.

Categories and Subject Descriptors (according to ACM CCS): I.4.1 [IMAGE PROCESSING AND COMPUTER VISION]: Digitization and Image Capture—Scanning, H.5.1 [INFORMATION INTERFACES AND PRESENTATION]: Multimedia Information Systems—Artificial, augmented, and virtual realities

1. Introduction

Museums all over the world are nowadays facing an important challenge: digitalization of the objects in their collections ([CCG*04,VBB05,Ris06]). This is a very complicated issue: economic factors like initial investment in hardware and know-how acquisitions mix with editorial and managerial choices like safe data storage, copyright protection, policy for the disseminations of the data, choices of the presentation modalities, etc. Only few museums may afford an in house digitalization laboratory with specialized well trained technicians. For these reasons to share the results of some of the current experiences, may provide some insight for the mixed community of curators and computer graphics technicians involved into such programs. This paper is aimed to provide a report about a joint exploration of these issues during a local experience that has involved our two institutions: the Museo Diocesano of Catania and the Department of Mathematics and Informatics of Catania University. We decided to join our forces and expertises to digitalize some selected objects in the Museum in order to gain some direct experience and know-how and to design a sustainable, scientifically sound and effective pipeline for a more systematic and comprehensive digitalization effort. The problem is made more complex because the objects in most of the collections are of heterogenous nature: paintings, sculptures in different materials, clay, textiles, mixed media art, old and fragile artifacts etc., they all require proper and dedicated way to be digitalized and to be processed into a coherent pipeline that guarantees scientifically sound representation and fruitful usage. It is clear that no single digitalization technology could properly address all the need of a such variegated collection. Since the know-how and methods for planar art digitalizations (paintings and textiles) is by now well developed and standardized we choose to focus our exploratory experiences into the digitization of three kinds of artifacts:

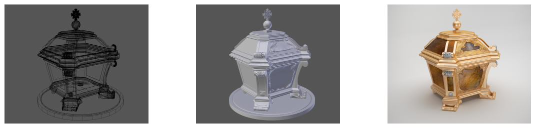
1. A mixed media liturgical cointaner (urn for Eucharist public adoration).
2. Several unmovable marble sculptures, both in “tutto tondo” and in bas-relief, located in room A of the museum;
3. A mixed media (ivory, textile, wood) box;

The choice of these three categories of objects has been done both on the practical need to make the work easier (they were not too fragile, could be easily accessed in the Museum rooms or in nearby churches, they are of small to middle size) and to the need to test the efficacy of some technologies in facing different objects and materials. The technologies that we could access and test have been: 3D laser scanning, uncalibrated image based modeling, recon-

DOI: 10.2312/stag.20141239

(a) (b) (c)

Figure 1: *Three different views of the tabernacle.*



(a) (b) (c)

Figure 2: *(a) Wire-frame model of the tabernacle in Fig. 1. (b) The solid model without textures: (c) The model with the final textures after the rendering.*

struction and simple augmented reality. These paper reports about the difficulties we had to face these issues solve and the results that we have obtained in these different cases.

2. A Wooden Tabernacle

The Catholic tradition and rituals prescribes for the evening before Good Friday that the consecrated bred is exposed for prayer and adoration in a very solemn way. It is hence customary to set up scenographic displays to this aim: the consecrated bred is put inside decorated wooden boxes that are used only for this occasion. This explains the presence of many very elaborated wooden boxes frequently complemented by silver or even gold decorations. Among the treasures in a church in Catania you may find a beautiful urn produced perhaps at the middle of XIX century. It is a very well preserved object and it is usually on display in a lateral altar of this church. The creation of a digital copy of this object is problematic because of several issues:

1. It is made of composite material with different reflective properties and cannot be scanned in a standard way by a conventional 3D laser.
2. A partial scan of the non reflective parts is problematic too, because of the occlusions and of the very elaborated geometry of the object.

The aim of the digitalization is to present the urn in a digital form, perhaps on the web or on a media kiosk and not for diagnostic or restoration purposes. Because of these challenges and finalities our laboratory has adopted a pure image based reconstruction strategy. The basic workflow has been as follows:

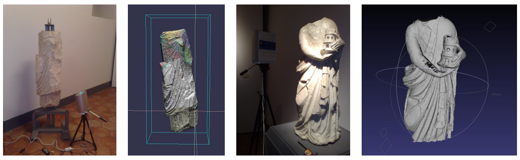
Acquisition and processing of images: a comprehensive set of high resolution photographs of the object has been shot (Fig. 1). This has been done with a Nikon D7000 camera in natural day light. Artificial light or flashes have been avoided because they create troubles with the reflective parts of the box. A set of reference photograph of the surrounding environment has been also acquired in order to reproduce at rendering time the original colors and environmental mood. The photographs have been cleaned, filtered, enhanced, partially rectified and finalized to become a set of references. Care has been devoted to acquire the original textures especially for the painted wood regions that the maker made into imitation of turtle bones. For the chiseled areas of the box and for the metallic decoration the original photographies have been processed in order to be used for the successive phases of fine displacement and normal baking.

Model planning: before even importing the images into a 3D modeler a careful planning has been layout. In particular we have taken into account among the others the following factors: symmetries, segmentation into separate subparts, level of detail required for each sub-part (some of them have to be fully 3D modeled, some of them are better reproduced with the use of normal maps and displacement maps), intended final usage for video and image production.

Geometric modeling of the 3D meshes has been done in Blender 2.70. An experienced 3D artist has reproduced with great care the geometric details and all the surfaces that produce the visual reproduction of the original object. This kind of reproduction is visually quite accurate, but is not, in any way intended to substitute more technical, metrical and dimensional reconstructions that are a must if diagnosis and restoration of the object should be performed (Fig. 2). The final geometry includes about 700k vertices. We choose as a renderer the Cycle engine inside Blender 2.70 and illuminated the Tabernacle with and environment light obtained from the reference photographs. The most problematic steps at this stage have been: the correct choice of specularity for the golden/silver parts, the extraction from the reference pictures of the pseudo-turtle pattern, the baking of normal and displacement maps for the chiseled and finely decorated areas of the box. Color grading at this stage has taken several tries and experiments. A turntable 360 degrees animation in HD has been also produced ([httc]).

3. The objects in room A

The high-definition 3D laser scanner has been applied to archaeological research to construct geometric models with different characteristics. Most 3D scanning work has been carried out to digitize objects of an intermediate size, such as settlement structures, statues, and vessels ([GMS*10, ACP*10, SST08]). The case studies to test the 3D digital restoration, presented below, were chosen because they presented different levels of difficulty and to demonstrate how the application of this technique may offer elements for the interpretation. The objects that are scanned are the marble present in room A of the museum. They are found during ex-



(a) (b) (c) (d)

Figure 3: *(a) A female torso. (b) The 3D model of the object. (c) Statue of Fortitude. (d) The 3D model of the statue.*

(a) (b) (c) (d)

Figure 4: *(a) The bas-relief of the Master of Miletus. (b) The 3D model after the filling holes. (c) A medieval wooden box. (d) The 3D model of the box.*

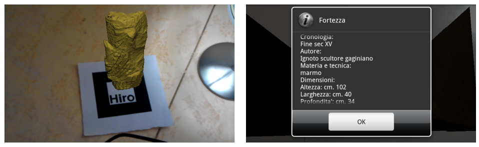
cavation and maintenance work in the Cathedral of Catania. They attest the different phases of the life of the building. We have acquired also a medieval wooden box used as reliquary that is shown in the same room. The scanned works are:

1. A female torso with a robe knotted on the side (Fig. 3(a)).
2. Allegorical statue of the virtue of fortitude with the characteristic tower with three windows representing the Trinity. The statue, without the head, could also be the representation of the St. Barbara (Fig. 3(c)).
3. Bas-relief of the Master of Miletus representing Christ between the St. Peter and Paul. This is an important sculpture because it provides the oldest representation of the "Liotro" elephant, symbol of the city (Fig. 4(a)).
4. A medieval wooden box used as reliquary. It has inlays tiles in ivory and colored wood with reflecting surface (Fig. 4(c)).

The 3D models were obtained by the technique of an optical triangulation scanner (Figs. 3(b), 4(b), 3(d), 4(d)). The maneuverable and small scanner NextEngine has proved very effective for scanning because the statues, nontransferable elsewhere for the scan, were located very close to the wall of the exhibition hall of the museum. These models have been used to develop the Augmented Reality tool described in Section 4.

4. Augmented Reality

Virtual reality allows the 3D visualization of concepts, objects, or spaces and their contextualization through the creation of a visual framework in which data is displayed. VR also enables interaction with data organized in 3D, facilitating the interaction between operator, data, and information in order to enhance the sensorial perception [HK09].



(a) (b)

Figure 5: *(a) The 3D model in a real environment. The marker "Hero" is associated to the model and if the user moves the mobile phone around the marker also the 3D model is moved. (b) The info of the object in Fig. 3(c). Since the app is prepared for the Italian Museum, the information are reported in Italian.*

One related emerging field is augmented reality (AR) where the simultaneous visualization of virtual data and the real world is performed [MY97,MTP,ZKWP,RBKS*,STG*12]. One of the objectives of AR is to bring the computer out of the desktop environment and into the world of non professional users. In contrast to VR, where the user is immersed in the world of the computer, AR incorporates the computer into the reality of the user. He can then interact with the real world in a natural way, with the computer providing enriching information and assistance (Fig. 5(a)). The final goal is to give an augmented reality experience to the visitors of the Museum aimed to revive virtually the objets and their locations on common mobile devices. The environment developed provides new ways of information access at the Museum in a user-friendly way [VIK*02, SPZ09]. We have chosen as device a common mobile phone, with the commercial framework ARToolworks which provides an high level programming tool for developing AR. ARToolworks is based on ARToolkit [httd], an open source library for Augmented Reality that allows many easy-to-use functions of Computer Vision to be applied for AR, the openGL library for high performance graphics and the rendering process. It gives the possibility to create Augmented Reality applications on any mobile device using a high level programming environment that allows the developer to set and manipulate the Video Tracking process and three-dimensional overlapping in a few simple steps without having to delve into the world of deep programming and the theory of Computer Vision. ARToolworks is integrated in Xcode, an Apple Integrated Development Environment; it uses only API approved by Apple and any application is "App-Store" compatible. Using a pattern that is recognized by the device, a three-dimensional model is associated with the pattern and the virtual model is shown like it is in the real world (Fig. 6). There is also the possibility to read some information about the object (Fig. 5(b)). The graphical engine inside the mobile device is able to handle three-dimensional environments without loss of data and without any delay within a certain memory limitation. This limit has a maximum of seven million polygons per second. However, the statues are

(a) (b) (c)

Figure 6: *(a) The AR version of the object in Fig. 3(a); (b) The AR version of the marble in Fig. 4(a); (c) the AR version of the statue in Fig. 3(c).*

composed of a greater number of polygons and must necessarily be reduced to fit within the limitations of the device, without compromising the aspect of the statues. For this operation, a filter contained in Meshlab software [htta] called "Quadric Edge Collapse Decimation" has been used. This filter has been applied many times by halving the number of faces each time.

The application that we have realized has been aimed to present to the visitor a virtual embedding of the sculptures in a digital "ad hoc" environment and to show at the same time some hypotheses about the virtual restoration of the sculptures. For example, the user may decide to watch through its digital display either the real Fortitude sculpture embedded in a virtual environment, either a partially reconstructed model (with the head) embedded in the real environment, either some other combination of realty and virtuality. An idea of how the system works may be obtained watching the video at [httb].

5. Conclusions

Although the experiences were different and perhaps lead to a different qualitative results we believe that they taught us a unique clear lesson: integration of different methodologies, human expertise of art trained personal, good design of the framework to propose the results to the public fruition are crucial for the success of any such project. Investments in hardware and know how should hence go to a catalogue of different state-of-the-art techniques and not to prefer only one of them. We believe, moreover, that the encouraging results obtained have their "secret ingredient" into the strong political will from the Museum curators to explore the possibilities that digital technology may offer to them and to the open and honest dialogue between them and the technical partners of this experience.

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