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CHER-Ob: A Tool for Shared Analysis in Cultural Heritage

Weiqi Shi, Eleni Kotoula, Kiraz Akoglu, Ying Yang, Holly Rushmeier

Yale University, Computer Graphics Group, New Haven, USA

Abstract

The study of cultural heritage involves many different activities, including digital data visualization, information analysis and sharing results. Current technologies focus on providing better tools for data representation and processing, neglecting the importance of analysis and sharing. In this paper, we present a software system, CHER-Ob, which offers powerful tools for evaluation and publication of the results of cultural heritage research, and at the same time supports visualization of various data formats. CHER-Ob also introduces the concept of Cultural Heritage Entity, which serves as a template for cultural heritage research and a model to manage projects. We use typical case studies of cultural heritage research to evaluate the system and demonstrate how it works.

Categories and Subject Descriptors (according to ACM CCS): I.3.2 [Computer Graphics]: Graphics Systems (C.2.1, C.2.4, C.3)—Software support

1. Introduction

The successful completion of a cultural heritage research project depends on contributions of experts in various fields, who may use different methodologies and terminology. Therefore, effective interaction with information provided by experts from different fields is necessary for a holistic approach towards interpretation and preservation of cultural heritage.

However, current digital technologies for cultural heritage research are faced with three major limitations in terms of information interaction and cooperation:

- **Management of Large Scale Data and Projects.** An important attribute of cultural heritage projects is the use of information from previous research on the object-site, which often contains ten or hundreds objects in different data formats. Researchers have to load each object one by one using proper tools for visualization and manually link and maintain its related files.
- **Lack of Analysis and Evaluation Methods.** Most digital technologies focus on data visualization, but are poor in information display, analysis and annotation, which play indispensable roles in cultural heritage research.
- **Documentation and Sharing.** Most digital analyzing tools fail to provide platforms for researchers to share results of their research in a formal way. In most cases, researchers use digital technologies only to visualize data and they have to turn to other software for documentation, which can be shared and propagated conveniently.

To solve the problems mentioned above, we develop an open-source software, CHER-Ob (for "Cultural HERitage Objects"), which provides powerful analysis and evaluation functions for cultural heritage research. The main contributions include:

- **Cultural Heritage Entity.** The cultural heritage entity (CHE) is introduced as the basic container of information about cultural heritage. CHEs serve as templates for researchers to build projects. Using a hierarchical storage model, CHE can efficiently maintain and manage all the objects and their related files.
- **Efficient Annotation System.** CHER-Ob provides convenient annotation APIs for various data formats. Multiple selection mechanisms and color encoding enable users to locate the area they want to annotate and differentiate annotations in different categories.
- **Automatic Report Generation.** CHER-Ob provides functions to generate research report in pdf format, which can summarize the project information clearly and efficiently.

2. Related Work

Current systems mainly focus on image and geometry processing. They are specialized and in most cases can only support a limited number of data formats. One of the most widely used software systems is MeshLab [CCR08], which can handle various 3D visualizations and operations, but is limited in its support for other formats, such as 2D images and RTI data. The same applies to Graphite [L08́] and GIMP [KK99], which are designed only for processing 3D data and 2D images separately. Hyper3D [KRF*14] is a software prototype system developed to support the visualization of various data formats, but by design is a data viewer rather than an analysis and sharing tool.

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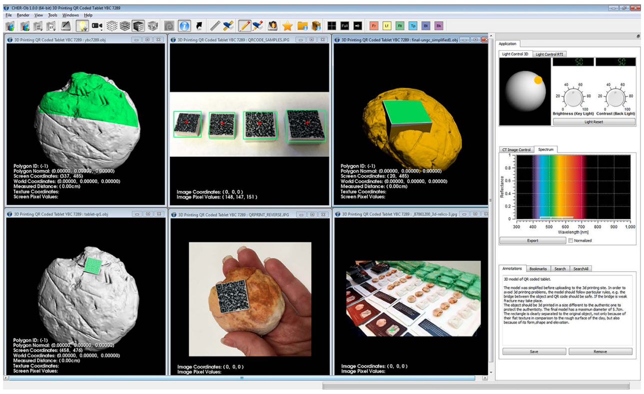


Figure 1: *CHER-Ob project screenshot*

Some systems provide analysis functionality for cultural heritage, such as 3DSA [YH14], which is a web-based annotation system for 3D objects. However, 3DSA only works for 3D objects and the annotations cannot be exported into other formats or interact with other tools, creating difficulties in analyzing and sharing. Many researches [GBBS11, HCS12] and systems [BvdWWdR14] are proposed to classify and cluster information related to certain topics from a variety of cultural researches. They offer efficient search tools and classifiers, but lack the functions of visualization and manipulation of certain data objects. As the most common software for accessing RTI files, RTI viewer [IVCL] only provides a very basic annotation API, which is integrated with bookmarks and limited to the highlight box.

3. System Overview

CHER-Ob provides powerful functions for analysis and annotation in order to meet the needs of cultural heritage research, which are different from the functionalities offered by current image and geometry processing tools. Compared with other sophisticated digital image processing tools, CHER-Ob is designed as a light-weight software, where system design decisions have been made based on the opinions of art conservators. QT APIs and VTK libraries are used for the implementation of the user interface and visualization.

Building on the capabilities of its predecessor, Hyper3D, CHER-Ob supports visualization and rendering of various data formats, including 2D images, 3D models with an illumination control system, computed tomography data, hyperspectral image and RTI data.

3.1. Cultural Heritage Entity

To take full advantage of previous cultural heritage projects and efficiently manage files, CHER-Ob introduces the concept of the Cultural Heritage Entity (CHE). It serves as the basic container of information about cultural heritage, either tangible (object or site) or intangible for organization, storage and interpretation. The CHE is different from a *Project* in CHER-Ob, which is defined as different types of studies related to CHEs that are focused on answering specific research questions. Researchers can build specific projects by importing information and data from one or more related CHEs, which includes the basic information of objects and previous knowledge. Also CHEs can be exported into different projects based on researchers' needs to solve different problems.

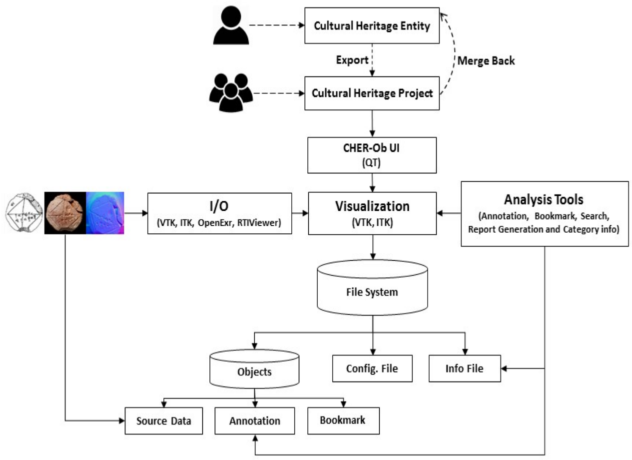


Figure 2: *CHER-Ob System Architecture*

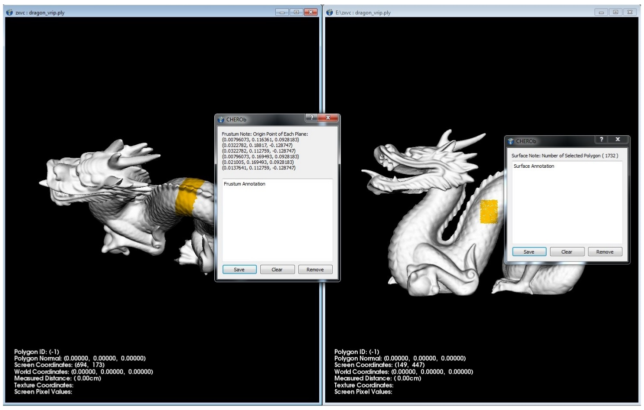
CHE manages files in a hierarchical model, where each object is a unit and related files are maintained by each object independently and separately. Each object in CHE consists of raw data, rendering and visualization information, previous annotations and bookmarks. Besides, Each CHE is accompanied by its metadata, which includes ten categories derived from the Getty Categories for the Description of Works of Art (CDWA) [BH06] and a user defined category labeled as others/miscellaneous (Figure 2).

3.2. Annotation System

In order to help conservators keep track of their own thoughts and share their perspectives, CHER-Ob provides powerful features for evaluation and annotation (Figure 3). The annotation system provides three different modes (point, surface, frustum).The annotations, applied to different data types, are categorized according to widely used standards which enable efficient search leading to an in depth interaction, not limited to generation and display of notes for a particular data type.

Since the annotation is based on selection, multiple annotation methods are offered due to the different selection mechanisms. For 2D images, RTI and CT data, points or areas can be selected based on pixels. For 3D models, vertices, surfaces or frustum(volume) can be selected. Taking into consideration the complex geometries of 3D models in cultural heritage research, CHER-Ob distinguishes between surface selection and frustum selection. Surface selection only selects the surface in a user specified rectangle area on the screen, such as a small patch or texture on the object. For frustum selection, the entire volume behind the screen is selected, such as the full head of a sculpture.

Apart from selections, color encoding is supported for annotation to represent different categories. All the notes can be saved or removed based on the needs of user. The notes are saved as a text file in order to share conveniently and maintained in the *Note* folder under the corresponding object. Annotations are searchable and can



Frustum annotation (left) selects part of the body behind the screen. Surface annotation (right) selects surface skin.

Figure 3: *Frustum annotation and Surface annotation*

be filtered by categories, which assists collaboration by saving time for all users.

3.3. Report Generation

For the purpose of sharing and publishing, CHER-Ob is designed to support automatic report generation, which can summarize the output of a project or CHE (Figure 4).

The report includes the project information, such as user name, the data of creation and descriptions, and details of each object, which contains the screenshot of the raw data, properties and annotations. The screenshot provides an intuitive visualization of the object, which are under default lighting and camera position. To display 3D objects comprehensively, screenshots from six directions (front, left, right, top, bottom and back) are taken by changing the camera position. The properties for each object reveal the information of raw data based on the data format such as resolutions.

To clearly match each annotation to the area where it is annotated, the screenshot images are labeled with numbers (annotation ids). For 2D images, the annotated area can be easily located by using the 2D coordinates of the selected pixels. For 3D models, the center point of selected surface or volumes is calculated and projected to the object surface in each screenshot direction. If the center point is visible from current camera position, it is assumed that the selected area can be seen in this screenshot and the annotation ids are labeled on the center point with 2D image coordinates transformed from 3D world coordinates.

4. Case Study and Application

The potential of the new software is demonstrated using two case studies, different in terms of scale and nature, focusing on object-based decision making and data management.

The first case study refers to a cuneiform tablet. A new CHE was created with the available information and visualizations about the cuneiform tablet under examination. Based on the CHE, a new project named "QR Coded Cuneiform Tablet 3D Printing" was created in CHER-Ob, with data from the CHE. The project aims to

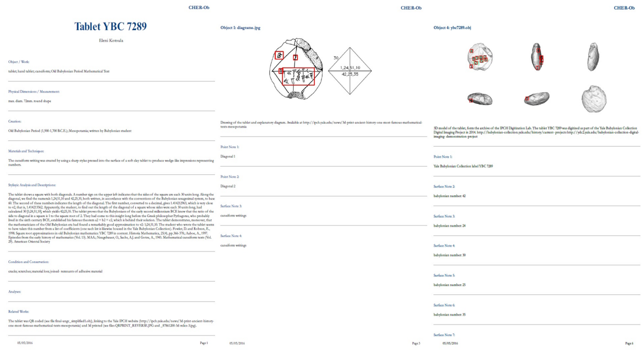
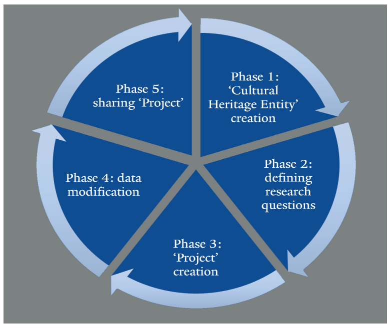


Figure 4: *Part of Report Generated by CHER-Ob*



In Phase 1, the user creates a CHE, providing the already existing information followed by Phase 2, where the research questions are defined, leading to a creation of a project in Phase 3. During the development of the project, in Phase 4, the data are modified, new information is added until its completion in Phase 5, where the project is shared.

Figure 5: *CHER-Ob pipeline*

document and assist in decision making for the QR coding of 3D model of the tablet and its 3D printing. (Figure 6).

The details of how the CHE and the project work in CHER-Ob are as follows. First, to create a new CHE, information was classified and maintained into eight categories: object/work, physical dimensions/measurements, creation, materials and techniques, stylistic analysis and descriptions, condition and conservation, exhibition/loans and legal issues, and documentation. Then, built on the CHE, the project was created, where the comparative analysis and visualizations are introduced to define appropriate version for 3D printing. The CHER-Ob project narrates the development of the QR coding and 3D printing, making it possible to follow. Different visualization statuses can be retrieved using bookmark and the specific information (i.e. keyword) can be located by search tools. When the project was finished, an option of merging the outcomes in project back to CHE base was provided to users. Since the 3D print is part of the object's museum life or biography, the documentation of CHE in CHER-Ob is complete only if the outcomes of the project were merged back to the CHE. In that sense the new knowledge generated from the project can be used by other projects and further explored as explained in Figure 5.

The second case study refers to a historic cemetery. It aims at documentation and management of the available dataset, explo-

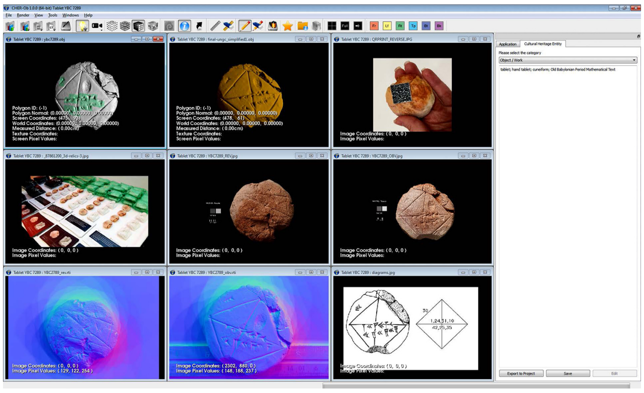


Figure 6: *CHER-Ob Cultural Heritage Entity screenshot*

ration of the RTIs, translations of inscriptions on gravestones and the results comparison of recent fieldwork with the archival information. The case study started with an existing CHE named "Jewish Cemetery", which included the archival information, such as a digitized historic plan and the cemetery registration book. The CHE was exported to a project ("Cemetery RTI Project") in order to be further developed. A set of RTI visualization captured in 2015 fieldwork was imported to the project, and the surface topography was examined virtually using the available rendering modes. Then, various annotations were introduced for analysis. Typically, surface notes were applied on the inscribed areas for the purpose of translations provided by different researchers. With the search and filter tools, the location of the RTI visualized stones were located in the plan. After the completion of the project, the updated plan as well as the RTIs were merged back in order to enrich the context of the CHE.

The "Cemetery RTI Project" is a part of a larger on-going project, which includes aerial photographs, RTIs, 3D models, 2D images, numerical data and multilingual text derived from archives and recent research. The support of various data format provides convenience and efficiency for this research project. Previous work [Cai14] [Cai16] and present collaborations provide with not only a complex dataset but also a fast growing one. Serving as the base of projects, the CHE of "Jewish Cemetery" could offer necessary information and be distributed to various researches to build specialized projects. Each individual project is based on the initially created CHE and will broaden the understanding about the site by incorporating existing information into the 3D model, documenting the stone degradation and linking material evidence to intangible aspects of the cemetery. Reports can automatically generated from these projects to record results and conclusions for the purpose of sharing.

The option to merge projects in CHER-Ob will potentially contribute in the successful completion of the project, which requires an advanced level of scientific cooperation. The outcomes of these projects are indispensable and the new information gathered as a result of these projects is merged into CHE. The links formed between datasets and the interaction between humans and data proposed by CHER-Ob is an efficient research methodology for further analysis and interpretation. CHER-Ob is capable of providing a holistic approach for the study of the cemetery, flexible enough to meet cultural heritage documentation needs. The customizable automatic report generation is useful for the presentation of project results, online publishing, digital and print archiving, and collaboration with non CHER-Ob users.

5. Conclusion

In this paper, we propose an open-source system, CHER-Ob, which provides an efficient platform for researchers to analyze the objects/sites and share their results with other professionals. CHER-Ob supports various data format visualization, multiple annotation methods, automatic report generation and Cultural Heritage Entity. The future work includes introducing user-role system, where different users may have different access to CHE, and improving the annotation system by providing image annotation functions. We hope our work can inspire more efforts to be made on developing tools for the evaluation and result sharing in the field of cultural heritage research.

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