

AN OPEN SOURCE APPLICATION FOR INTERACTIVE EXPLORATION OF CULTURAL HERITAGE 3D MODELS ON THE WEB.

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ABSTRACT

In recent years, the integration between laser scanning technology and photogrammetry has been proven to be a very effective methodology to provide high-resolution 3D models of heritage sites and cultural artifacts. Furthermore, the availability for faster connections to the Internet and for more performing servers and browsers have pushed the development of interesting web-based Virtual Reality applications. Several works published so far have demonstrated how Cultural Heritage (CH) can greatly benefit from 3D modelling and Virtual Reality applied to object or historical/archaeological site analysis, documentation, preservation and restoration. Virtual Reality environments created for these purposes represent very often an easy way to give accessibility to CH among a wide variety of users. However, these tools provide only limited knowledge about the element of interest which is represented, mainly geometric, color and texture characteristics of the object as it existed at time of survey: historical and artistic details are often omitted.

In this paper we present the development of a WebGis-based application which allows the user to interactively explore Cultural Heritage 3D models, integrating geometrical and non-geometrical information. While walking through the virtual reconstruction, the user can get information about historical, artistic and architectural aspects, which are usually found on the tour guides or specific books. The main aim of this interactive system is to provide the user with a completely new visit experience based on a free interactive exploration of the object (i. e. not constrained by any predefined pathway) and on the opportunity to get more detailed information on parts of interest in the form of papers, photos and videos, widening therefore his/her knowledge with respect to a simple and classical walk through.

The developed application is based on open source tools, thus providing full transparency on adopted methodology and on used data. The information system, based on a completely thin-client architecture, is a WebGIS platform seamlessly integrated with a Postgres DBMS and X3D file format for data representation. The architecture uses PHP and Mapscript/Mapserver for scripting, while Blender is adopted for model editing and format conversion between VRML2 and X3D.

1. INTRODUCTION

In recent years, advances in the field of survey and Internet related technology have opened up new opportunities and challenges for the development of web-based Virtual Reality applications. Namely, the integration between laser scanning technology and photogrammetry has proven to be a very effective methodology to provide high-resolution 3D models of heritage sites and cultural artifacts. Through this approach, the geometry and appearance of real objects can be recorded with high level of detail and accuracy. Several works published so far have demonstrated how Cultural Heritage (CH) can greatly benefit from 3D modeling applied to object or historical/archaeological site analysis, documentation, preservation and restoration (Barber et al. 2001, Guarnieri et al. 2004, Beraldin et al. 2005, Remondino et al. 2008). For instance, working in a 3D environment allows to digitally remove unwanted elements from the model and to view the object/site in his correct historical context. Virtual restoration can be used to improve the knowledge of a site without resorting to interventions often traumatic for the original artifact. Furthermore, CH can also benefit from the use of Virtual Reality (VR) and its integration with Hypermedia and Computer Graphics (CG). The advantages of using these technologies include the virtual reconstruction of buildings, sites or objects that no longer or only partially exist, the simulation of viewpoints not available in the real world, the direct interaction with virtual reproductions of artifacts, thus eliminating the risk of degradation.

Virtual Reality environments created around such 3D models represent very often an easy way to give accessibility to CH among a wide variety of users. However, these tools provide only limited knowledge about the element of interest which is represented, mainly geometric, color and texture characteristics of the object as it existed at time of survey: historical and artistic details are often omitted.

Besides the developments occurred in the field of survey, the growing availability of faster Internet connections and of more performing servers and browsers represents another key factor for the dissemination of 3D models to a wider audience through the Internet. Web-based applications have indeed many advantages as compared to standalone solutions, such as no need for installing large external programs, use of a common web browser with light plug-ins, cross-platform and centralized administration for data update, backup and storage. The introduction in recent years of the X3D file format has also opened up new perspectives for the dissemination of 3D models among remote users. Enabling binary data compression, this evolution of the Virtual Reality Modeling Language (VRML) can potentially overcome the issues related to the streaming over the web and the real-time exploration of very dense 3D models, as those derived by Terrestrial laser scanning measurements. Indeed, the large size of corresponding data files stored in VRML format (even hundreds of Megabytes) has often prevented users to navigate in such 3D virtual environments in seamless and flexible way, unless very performing PCs were available.

Given these premises, it is therefore authors's opinion that the integration of VR worlds into web-based applications will be the next step towards the dissemination of CH related contents to a wider audience. However topics such as the "truthlikeness" of virtual reality reconstructions (Ogleby 2005) and the efficient representation of virtual objects (Zara 2004) are still important issues in the field of VR applied to Cultural Heritage.

In this paper we present the development of a WebGIS-based application enabling the user to interactively explore a Cultural Heritage 3D model, which integrates geometrical and non-geometrical information. While walking through the virtual reconstruction, the user can get information about historical, artistic and architectural aspects, which are usually found on the tour guides or specific books. The main aim of this interactive system is to provide the user with a completely new visit experience based on a free interactive exploration of the object (i. e. not constrained by any predefined pathway) and on the opportunity to get more detailed information on parts of interest, widening therefore his/her knowledge with respect to a simple and classical walk through. Ancillary documentation about the object or site are presented in the form of papers, photos and videos. These kind of metadata are managed at multi-scale level by a properly designed information system in such a way that documentation can be related to the object or site as whole or to its single parts. For instance, in the case of an archaeological site the information system is designed to store metadata for both the whole site and the single stratigraphic excavations. Scale level at which information is still available to the user can be further narrowed down to parts of single objects, like inscriptions or paintings on pots, or numismatic finds or parts of a statue. The developed application is based on open source tools, thus providing full transparency on adopted methodology and on used data. The information system is a web platform based on a completely thin-client architecture. It seamlessly integrates a database management system (DBMS), PHP and Mapscript/Mapserver for scripting, Blender for model editing and data format conversion between VRML and X3D.

In the next Section a short description of the 3D models used to test our interactive application is provided. The software tools composing the system are presented in Section 3 while procedures adopted to generate interactive 3D models are described in Section 4. Some results of the interactive exploration system are discussed in Section 5 and finally Section 6 draws the conclusions.

2. EMPLOYED 3D MODELS

Our interactive exploration system has been tested on 3D models produced in different research projects, that were undertaken in the past years by our research group for documentation and preservation of Cultural Heritage objects.

Namely, three models have been used used in this work: the small medieval church of Pozzoveggiani, a bas-relief of Jesus Christ and an epigraphy (figure 1). The church, located 5 km from Padova, dates back to XIIIth century and represents an example of the interlacement between Carolingian-Othinian artistic culture and styles typically found along the Venice lagoon. The church was fully surveyed in 2003 both with a Time-of-Flight (TOF) terrestrial laser scanner (Leica HDS3000) and with photogrammetric methods as described in (Guarnieri et al., 2004). The aim of the work was to perform a comparison between laser scanner and photogrammetry-based 3D modeling, by assessing the metric accuracy of the 3D models achieved with both techniques. The bas-relief of Christ was surveyed with a close-range laser scanner, working on the principle of optical triangulation. Measurements were acquired with a

spatial resolution of 0.6 and an accuracy of 50 μm . The object is composed by a smooth rocky material (probably marble) and comes from the Mantova-Benavides collection hosted by the Museum of Archaeological and Art Sciences in Padua. The epigraphy was obtained by surveying an ancient milestone, preserved at the Museo Lapidario Maffeiano in Verona. Data were acquired with the same close-range laser scanner, setting a point spacing of 0.9 mm on average. The porous surface of the artefact shows a set of inscriptions some of which are clearly visible while others are less distinguishable, being eroded by time and weather.

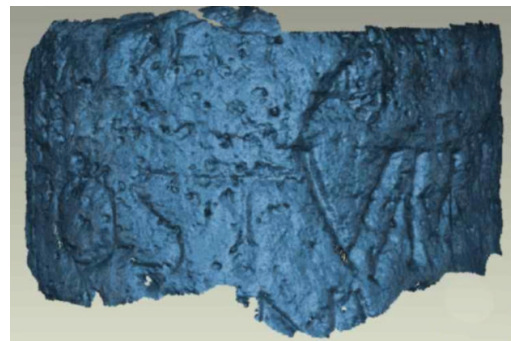
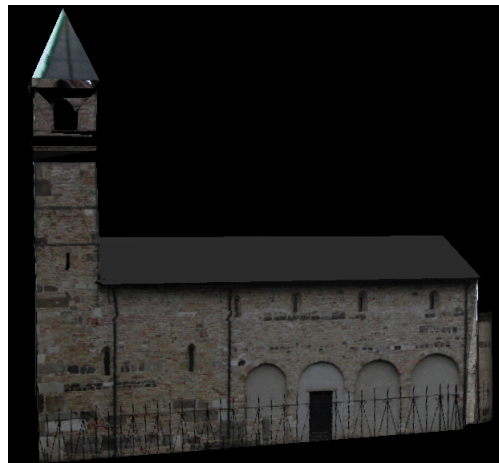


Figure 1: The employed 3D models.

From top: Pozzoveggiani church, Christ bas-relief, epigraphy bas-relief.

3. SYSTEM ARCHITECTURE

The components employed for the development of the web-based application include a database management system, a web server, a mapping engine which deals with geodetic data and a 3D browser plug-in for viewing interactive models. More in detail, the architecture is made up of PostgreSQL as DBMS, Blender as modeler, VRML/X3D as 3D format for the models (see figure 2).

PostgreSQL is a full open-source object-relational DBMS (ORDBMS) supporting almost all SQL constructs. It provides all the characteristics needed by a management system to deal with data warehousing. In this project PostgreSQL is used not only to store metadata and attributes related to objects but also to connect all available information with corresponding 3D models.

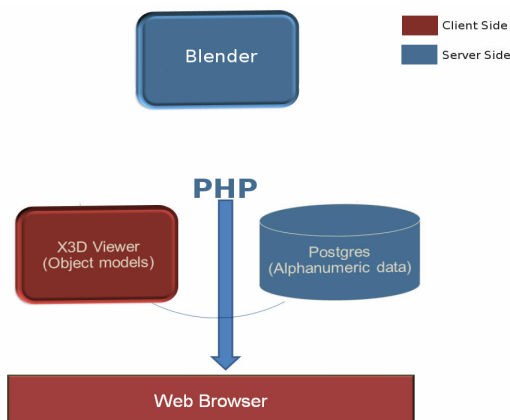


Figure 2: Conceptual structure of the interactive system

Grossi and Pirotti (2007) and Grossi (2004) have shown how data related to an archaeological site can be well managed through a web-based application developed with PostgreSQL: consultation, completion of predefined modules, data mining, spatial analysis and data visualization are fully allowed.

X3D is a scalable and open software standard for defining and communicating real-time, interactive 3D content for visual effects and behavioral modeling. Developed by the Web3D Consortium, this evolution of VRML can be used across hardware devices and in a broad range of applications including CAD, visual simulation, medical visualization, GIS, entertainment, educational, and multimedia presentations. Many light and interactive X3D plug-ins are widely available for both commercial, free or open-source authoring softwares and for players and browsers. This mark-up language improves upon VRML by including a number of tags for events, environment and lighting, animation and user interaction, what makes it very versatile for creating virtual reality for CH. Another useful characteristic of X3D relies in the fact that it can be compressed to a binary format therefore improving the size of the models that are sent over the web.

Blender is a free open source 3D content creation suite enabling the user to create stunning 3D models and interactive 3D applications. The software, available for several operating systems, has a depth and breadth of features comparable to commercial, proprietary, high end and mid range 3D software. The latest version (2.48a) provides full X3D import/export capabilities, thus making it perfectly suitable for edit and exporting 3D models in VRML/X3D format, ready to be employed in web applications.

PHP is the web-scripting language used for server-side scripting enabling operators to link dynamically objects using forms from web-pages (Pirotti and Pontin 2004). In the X3D format the “anchor” tag provides the ability to link a portion or an entire object to a web page, thus allowing to embed 3D models in web pages.

All system components have been properly integrated using a web-scripting language in order to achieve the following goals:

- Access to maps of the territory of interest, such as archaeological sites or cultural heritage points of interest
- Interaction on 2D maps of the region for consultation of the overview of the site – for example name of the region or city where it is located or simply general information
- Access to information layers (such as the stratigraphic unit) of objects of interest at different scales – for example numismatic objects or ceramics can be contained in a bigger object which can be a specific monument which in turn can be part of an excavation campaign. In such example we have three different object scales: excavation site, monument, and numismatic piece. Each of them can have its own set of attributes which can be associated on a one-to-one or one-to-many basis.
- Specific objects of interest can be queried and viewed as 3D models directly on the web – for example a piece of an important statue can be viewed and queried thus accessing attributes linked to it as a whole or to parts of it.

4. MODEL PROCESSING FOR INTERACTIVE NAVIGATION

In order to provide the user with full web-access to detailed 3D models, as those derived from laser scanning measurements, following two procedures are applied: model simplification and model segmentation. The former is aimed to decrease the size of the data being transmitted over TCP/IP protocol, while the latter is used to define on the 3D model user-selectable areas of interest. These goals can be achieved by using both commercial and open-source 3D modelling softwares; in our project we decided to base the development of our interactive system on open-source software only. Indeed with this approach code and tools implemented for interactive exploration of the models can be fully and freely accessed by third-party subjects and project team members, thus allowing the introduction of further improvements through a cost-effective collaborative work. Using open-source tools opens the possibility to invest project budget on human resources instead of on license purchase.

4.1 Model simplification

The first step is of course to measure the object with photogrammetric methods or laser scanner in order to produce a reliable 3D model with acceptable accuracy and detail. From this data source other rescaled and simplified sub-models (“children”) are created in Blender for optimal visualization via web. The goal of this processing step is to diminish the size of the 3D model without losing important details. However this is not an immediate task as the best ratio between level of detail and file size should be found. Usually the criteria adopted for determining such ratio depends on internet speed of clients and performance of client machines. Once the original meshed model has been imported in Blender, pre-processing tools are applied for optimal ambient lighting, material customization, texturing and so on. Next the edited model is differently resampled in order to have a coarse resolution 3D model (hereinafter “overview”) of the whole object and more detailed

parts which can be separately exported and viewed as “children” of the overview model. By default Blender automatically keeps high level of detail where there is high complexity and removes detail in simpler surfaces (figure 3). The generation of “children” models is accomplished through the segmentation routine described in the following subsection. Scripts in Python language can be used to automate the simplification procedure: multiple resolution models can be easily generated from the same data source, whether it is the original 3D model or a “child” derived by segmentation.

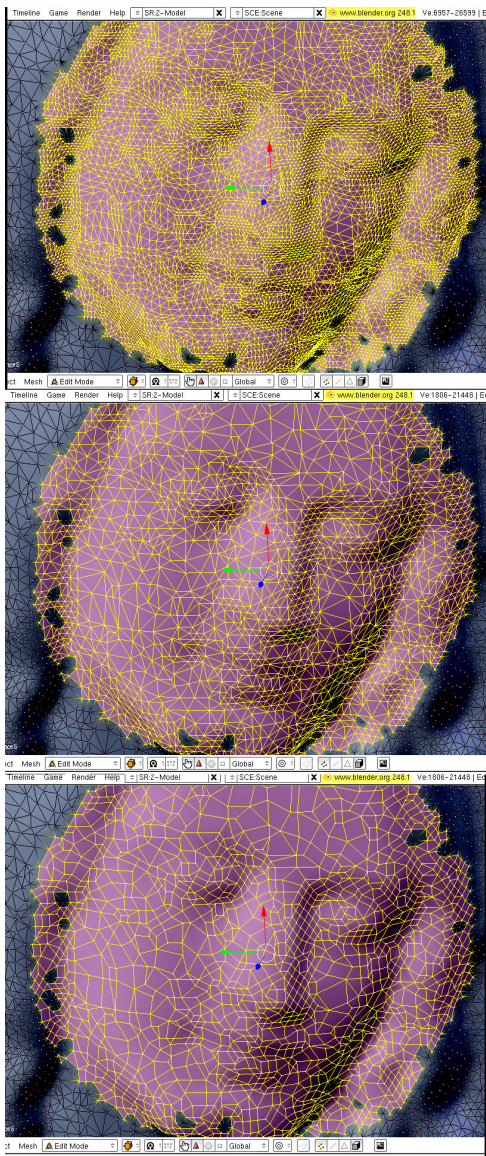


Figure 3: example of model simplification applied to the face of the Christ.

4.2 Model segmentation

In order to create an interactive product, the 3D model is manually subdivided into different parts (entities) corresponding to the areas for which attributes and/or metadata are available (figure 4). Then each entity is separately saved in X3D format, through which object interaction can be easily provided as described in the next subsection. In order to perform object

segmentation, semantic logic can be used on attribute data. For example the epigraphy used for the test presents some inscriptions engraved in the rock; information on that features can be saved as attribute data (meaning of the string, language used, date it was engraved, historical meaning etc...). All this information can be associated to the part with the engraving, whereas the rest of the object can be associated to more general data (material used, type of restoration needed etc...).

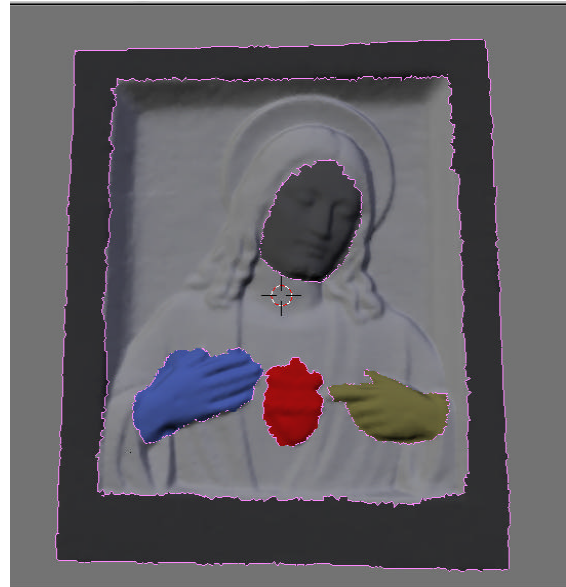


Figure 4: Example of the segmentation process based on symbolic meaning.

4.3 Connecting attributes and metadata

The final step deals with the linking of segmented areas (or the whole model) to respective data. This is not an easy task as it must be clear beforehand which logic to adopt for the segmentation. In the example of the bas-relief shown in figure 4, information was assigned to separate areas which represented physical characteristics (face, sacred heart, hand position) because it was interesting to highlight the symbolic meaning of these parts. Alternatively, model segmentation could be aimed at documenting the features of the artistic technique exploited to create the different parts of the artefact. Semantic logic can therefore lead to multiple types of segmentation because significant associations can intersect one another.

In our system, model interactivity relies on the combination of PHP, PostgreSQL and X3D data format. Basically attributes and metadata are connected to the corresponding entity by adding in the X3D data file an html-like tag which contains both the link (URL) to the web page where data will be displayed, and a reference ID stored in a record of the PostgreSQL database. When the user clicks with the mouse on a selectable area of the overview model, the web page is dynamically generated by PHP script running on the server and all information (high resolution 3D model of selected entity, metadata and attributes) related to such ID is shown to the user.

5. 3D MODEL INTERACTIVE EXPLORATION

The main goal of the web-based application we have developed, relies on the dissemination of Cultural Heritage related information through 3D modeling. The basic idea is to enable

remote users to get more insights on cultural, historical and artistic aspects related to CH objects. To test our system we have simulated a repository of CH 3D models which can be accessed at first through a common web page. We assumed that the repository could be visited in two ways: by navigating through the different levels composing the site or by directly exploring the 3D models. In the former case the user can retrieve the information stored in the PostgreSQL database selecting as usual the links disseminated in the html pages, while in the latter interactive exploration is enabled by selecting specific links located in the web site introductory page. Such links allows the system to activate the data streaming from server to the client according to the user connection speed. To this aim we have taken into account just three kind of connections: analogue modem (at least 56.6 kbps), ADSL and T1/LAN. Depending on the choosen option, an overview model with proper resolution is displayed on the user client. This approach clearly implies that more overview and “children” models have to be derived from the same original 3D model with different spatial resolutions. As previously mentioned, determining the optimal value for the mesh simplification is a difficult task as it depends upon client connection speed and client hardware performance. This part of the work is currently in progress, however at the time of writing the interactive navigation system can be run locally as standalone application on server side. In the current implementation after the potential user has selected the html link corresponding to its connection speed, a 3D model with proper resolution is sent to the user and displayed on its browser. To activate this functionality an X3D plug-in should be firstly downloaded and installed on client PC. The 3D model can then be explored with classical VRML tools, like panning, zooming, rotation and so on. As mentioned before, as soon as the user clicks with the mouse on any part of the model, a two frame-window opens showing on the left the whole model or the selected part at higher resolution and on the right the corresponding metadata (figure 5). If different kind of attributes (documents, photos, videos, etc.) are connected to the picked area or to the entire model, then a pop-up menu displays enabling the user to refine its choice by selecting the desired option. Related attributes are shown again on the right frame. This procedure conceptually allows to explore a 3D model through different level of information according with the complexity of the object being displayed and the amount of available attributes. The use of our interactive system could be therefore potentially extended to the virtual exploration of a more complex structure such as an archaeological site. During excavation campaigns, the finds are typically classified into different stratigraphic units (SU) according to some specific criteria. By exploiting the concept of SU, remote users could explore with our application the virtualization of a whole archaeological site accessing 3D models of finds and related information organized on different layers. Despite this would require an extensive 3D modeling work, constant advances in the field of surveying technology and computer science make such objective not unrealistic at all.

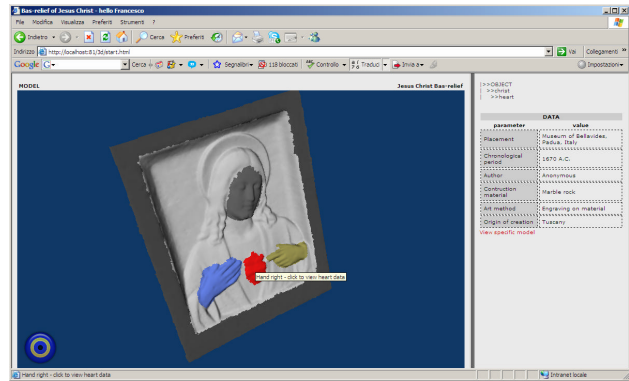


Figure 5: Visualization of the 3D model and related attributes .

6. CONCLUSIONS

In this paper we have presented a WebGIS application aimed at the interactive navigation of Cultural Heritage 3D models by remote users. The developed system allows to integrate both geometrical and non-geometrical information, i.e. metadata and attributes data like documents, photos, videos and so on. All the functionalities have been implemented resorting to open source tools and softwares in order to provide full transparency on adopted methodology and on used data. Interactivity is obtained through the combined use of X3D file format, PHP scripting and PostgreSQL relational database. In addition, model segmentation is performed according to object complexity and available information. Model simplification is a further pre-processing step required to optimize model transmission across the web: 3D models derived from terrestrial laser scanning and/or close-range photogrammetry are sub-sampled according to the user's connection speed and hardware performance. In order to determine the optimal ratio level of detail and model file size a set of tests will be carried out, taking into account three different connection speeds: analogue modem (at least 56.6 kbps), ADSL and T1/LAN. However this topic is of relative significance as constant technology advances in computing will likely make more and more easy accessing detailed 3D models via web, thus opening the door to new opportunities and perspectives for the development of web-based Virtual Reality applications.

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