Virtual Heritage: The cases of the Byzantine Crypt of Santa Cristina and Temple C of Selinunte / Patrimoine virtuel : Les cas de la crypte byzantine de Sainte-Christine et du temple C de Sélinonte

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Virtual heritage: the cases of the byzantine crypt of Santa Cristina and temple C of Selinunte

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Abstract. This paper presents a summary of the 3-D modelling work that was accomplished in preparing multimedia products for cultural heritage interpretation and entertainment. The two cases presented are the Byzantine Crypt of Santa Cristina, Apulia and temple C of Selinunte, Sicily. The core of the approach is based upon high-resolution photo-realistic texture mapping onto 3-D models generated from range images. It is shown that three-dimensional modelling from range imaging is an effective way to present the spatial information about those two environments. The integration of both photogrammetric and CAD modelling complements this approach. Results on a CDROM, a DVD, virtual 3-D theatre, holograms and video animations are presented for these projects.

1. INTRODUCTION

In recent years, high-resolution recording (as-built reality) of heritage sites has stimulated a lot of research in computer graphics and vision. If the only purpose is the generation of photo-realistic images for visualization, then purely image-based rendering techniques offer a general solution. However, if the goal is to analyze the works, to preserve and share a record of their geometry and appearance, then explicit shape information must be acquired. A 3-D model contains a wealth of information that can be analyzed and enhanced [1]. Sites that must be closed for conservation reasons can still be studied and visited. Virtual restoration can be used to improve the legibility of textual information, without turning to interventions often traumatic for the original copy. Elements that were added over the years can be removed and the digital 3D model of a site can then be viewed in the correct historical context. Multimedia CDROMs about the history associated to a particular historical or archaeological site, can use spatial information instead of the usual 2D images that are flat and don’t show the three-dimensionality of that site or environment. The core of the approach presented here is based upon high-resolution photo-realistic texture mapping onto 3-D models generated from range images. The integration of both photogrammetric and CAD modelling complements this approach. It is shown that three-dimensional modelling from range imaging is an effective way to present the spatial information about these two sites. The first site is the Byzantine Crypt known as the Crypt of Santa Cristina (see Figure 1), which is located in Carpignano (LE), Italy.

a)

b)

Figure 1. Byzantine Crypt, a) two outside entrances, b) interior located underground.

The second site is Temple C of Selinunte, Sicily. For the site of Selinunte, a mixture of technologies is also planned. For the acquisition of 3D information, both laser scanning and digital photographs using a calibrated camera were acquired. Three-dimensional modelling was performed using two different 3-D laser scanners, photogrammetry and CAD. At the moment the museum room (Figure 2a) containing artefacts from the site in Selinunte was modelled using a mixture of the above-mentioned technologies and later this year, work will start on building a CAD reconstruction from historical information of temple C of the Acropolis of Selinunte (Figure 2b). Results on a CDROM, a DVD, virtual 3-D theatre, holograms and video animations are presented for these projects.

a)

b)

Figure 2. Selinunte a) Museum room dedicated to Selinunte, b) Temple C as of 2003 AD.

2. 3-D INFORMATION FOR CULTURAL HERITAGE INTERPRETATION AND ENTERTAINMENT

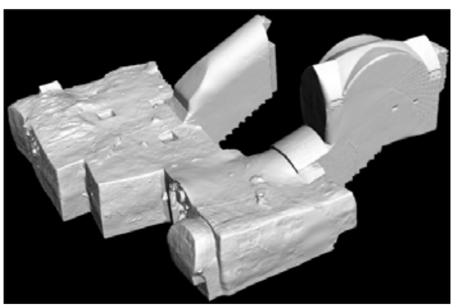
When presenting the history of a heritage site, the use of spatial information becomes very important in order to facilitate an understanding of that particular site. One can resort to hand drawn or computer generated isometric views, CAD models based on more of less reality and 3-D models built from reality. The source of information includes among other things drawing/paintings, papers/digital photographs, or laser scanner data. Some of these provide dimensions directly but others need indirect ways to get scale and/or dimensions. A description of the procedure is given for the Byzantine Crypt. For Selinunte, partial results will be shown towards the end of the paper.

We opted to represent the Byzantine Crypt of Santa Cristina using both photogrammetric techniques for the outside (using ShapeCapture software), and, for the inside dense 3D laser scanner information combined with high-resolution colour images. Irregularly shaded walls covered with a number of fairly well preserved frescoes made us decide to model the inside with a laser scanner. During the course of history, a Baroque altar was added (1775 AD) along with three pillars that replaced one that collapsed. These elements can all be removed in the 3-D model so the site could be viewed in the correct historical context. Many aspects of sensing and modelling must be understood before starting such a large project. The typical processing pipeline used for 3D modelling includes geometric modelling and appearance modelling. These are well documented in references [2-3,9]. Here, we summarize what was done for the Byzantine Crypt. The detailed technical aspects of the project are described in Beraldin et al. [4]. Other virtual heritage projects describe the different steps used for 3-D modelling and visualization [5-7].

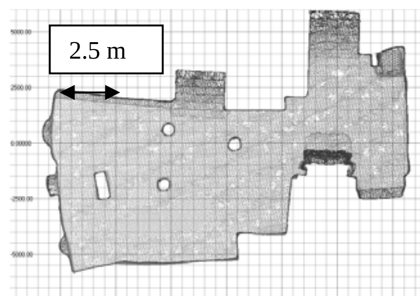
3. MODELLING TECHNIQUES USED FOR THE BYZANTINE CRYPT

3.1 Geometric Modelling

A model is a digital representation of the object or site on which one can perform operations. Acquiring dense 3D data of surfaces has been a hot topic of research in the last 20 years [8]. Though not as mature as photography, 3D imaging is seeing new applications emerging every year [5-7]. Numerous commercial systems are available to measure dense 3D data. The Byzantine Crypt is relatively large (16.5 m by 10 m by 2.5 m) and we wanted to model it with a fairly high spatial resolution. For these kinds of environments, there are not a lot of range cameras on the market that could provide us with the desired level of spatial resolution and low measurement uncertainty [8]. This range of distances represents the transition between optical triangulation and time of flight technologies [9].



a)



b)

Figure 3. Complete 3D model of the Byzantine Crypt, a) view from outside shown with synthetic shading, b) floor plan generated from an orthographic view of the 3D model.

In order to create a dense 3D model of the Byzantine Crypt, a MENSI SOISIC-2000 scanner was used. This triangulation-based laser scanner can acquire 3D images at a minimal distance of 0.8 m and at up to 10 m. The range uncertainty on a cooperative surface at 2.5 m is about 0.4 mm (1 sigma) and the data rate is 100-3D points per second. To make the scanning time manageable, it was decided to use a sampling step on the mesh of 5 mm (spatial resolution of the model mesh). The range uncertainty after pair-wise 3-D image alignment gave about 0.8 mm (1 sigma) at a distance of 2.5 m. Figure 3 present the complete 3D model (without colour information) that would appear if one could see through the ground. From this model, a floor plan was created. The generation of the model was done with the Polyworks Modeler software from Innovmetric.

3.2 Appearance (Colour Texture)

Appearance modelling includes methods like Image Perspective Techniques (IPT) and Reflectance Modelling (RM). The true appearance of an object is the result of the interaction of light with material. The knowledge of such information is important in order to reproduce hypothetical lighting conditions under varying observation points. For this project, texture mapping using IPT was chosen (with TexCapture software). With current CCD and CMOS technology, access to high quality texture images for IPT is now within reach of everyone. Though the Mensi provides 2D images from its internal video camera, the resolution and colour quality is not acceptable for our application. So a lens-interchangeable SLR-type 6-MegaPixel digital camera was used for the texture acquisition. Proper texturing of the 3D model requires special lighting fixtures in order to control illumination. Good uniformity of the illumination is essential in order to ease the virtual restoration tasks and improve the visual quality of a textured model.

4.0 CDROM AND VIDEO ANIMATION: CARPINIANA

Realistic estimate of the time to acquire the range images, build a 3D model and the determination of the required quality of model is very critical for such a project. For this site, with an average scan time on the walls of 80 minutes per 3D image, a total of 92 hours were spent in the Crypt. During that time, fifty 3D images were acquired for the Crypt along with thirty 3D images for the altar. The 3D model was created over a period of one month. The acquisition of the texture took 3 days and the actual mapping was done in 4 days.

A number of models with different levels of complexity were created from the original data. At the highest quality, the spatial resolution on the wall is about 5 mm and on the ceiling and floor, 15 mm. The range uncertainty is about 0.8 mm. We are currently working with 3 models: one 4.6 million-polygonal un-textured model (10 mm resolution) of the complete Crypt, a 12.8 million-polygon fully textured model (5 mm resolution) of one half of the Crypt (contains the two apses), and, a lighter textured model with 0.4 million polygons. These different models were further transformed in order to fit the format used in a CDROM. All of these representations are aimed at showing the three-dimensionality of the site and visualize artefact that are not visible in a typical visit to the site. A movie called “Carpiniana” showing a fly through of the Byzantine Crypt was also prepared. Snapshots of the CDROM and Video animation are shown on Figure 4 and Figure 5 respectively. When the animation was realized, i.e. year 2002, the computing power was not sufficient to deal with the high-resolution model. The software 3D studio Max helped create the animation. For Carpiniana, the model contained 400 000 faces, 1/5 of the maximum texture resolution, 13 lights, 5000 frames at a 720X576 resolution. Today, the full resolution (shape & texture) can be used along with a more complex lighting arrangement. The presentation of the Byzantine Crypt is now available through a virtual reality theatre (with “il teatro virtuale” software) that can display the full resolution model and allow the navigation inside the Crypt for further study. A number of large format (1.8m by 0.85m) holograms were also produced from the digital 3-D model (see Figure 6).

a) b)

Figure 4 Some screen snapshots for the CDROM CARPINIANA: a) entrance page, b) use of orthophotos generated from 3D model to navigate through the frescoes.

a) b)

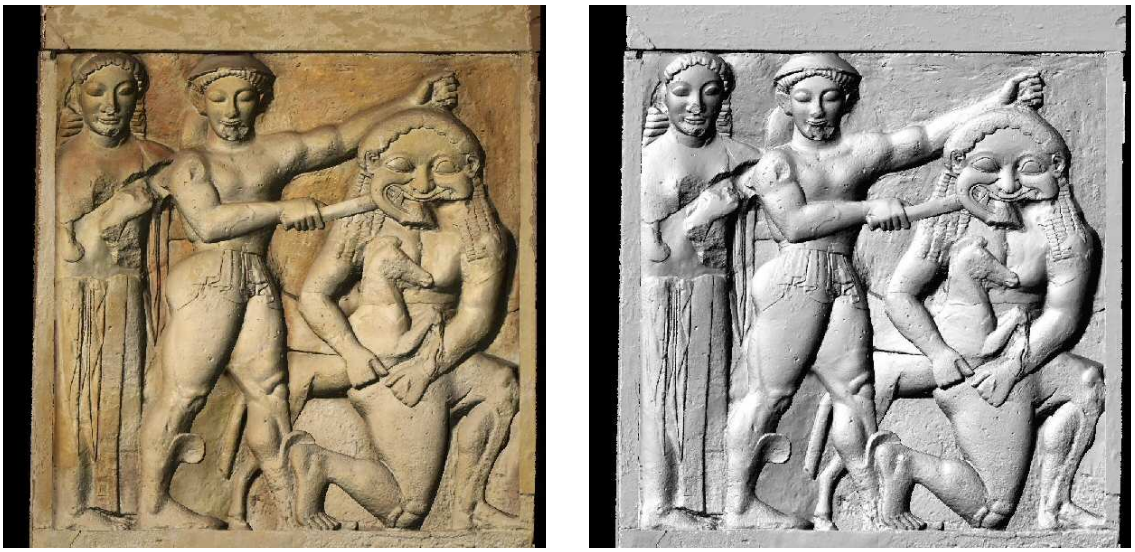
Figure 5 Still images taken from the movie included on the DVD: a) view of crypt without texture, b) view of main pillar with texture.

a) b)

Figure 6 Other representation of the work on the Byzantine Crypt: a) large format hologram (1.8m by 0.85 m), b) virtual reality theatre.

5.0 TEMPLE C OF SELINUNTE (6th century BC)

The project that started in 2003 is divided into two broad steps, the first step saw the modelling of the frieze of temple C of Selinunte using 3D laser scanning and the second step will see the reconstruction of temple C of the Acropolis of Selinunte using CAD tools. The CAD model will be based on historical information available at the University of Lecce and at the “Museo Archeologico Regionale” of Palermo, Sicily.

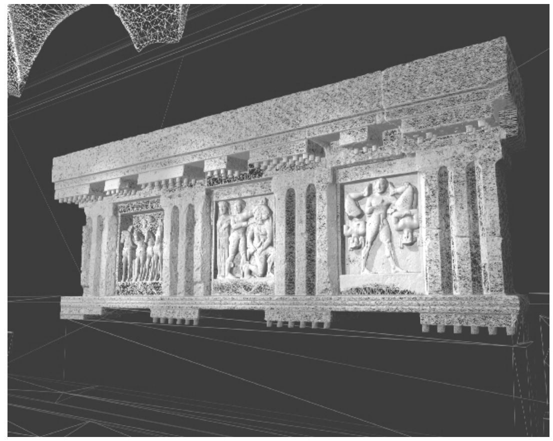


a) b)

Figure 7. Model of the Metope “Perseo and Medusa”, a) texture-mapped 3D model, b) shaded view of the same 3D model.

Figure 7 shows the results of the modelling of a Metope known as “Perseo and Medusa”. Both 3D laser scanning and texture mapping were used to create this model in a manner similar to the one described earlier. The same technique was applied on the other two Metopes associated to temple C. The average size of the three Metopes is 1m × 1m × 0.4m.The 3D model of the frieze from Temple C including the three Metopes is shown on Figure 8. We continued the laser scanning work using both the Minolta and Mensi laser scanners on different sections inside the museum room. The first scanner was used to acquire details in the order of 0.5 mm and the second scanner captured details in the range of 2-10 mm. The rest of the 3D model of the room was created using photogrammetry-based modelling techniques and some simple CAD modelling. A rendering of the complete museum room dedicated to Selinunte is shown on Figure 9. Later this year, the work described above will be integrated with the virtual reconstruction of Temple C.

a)

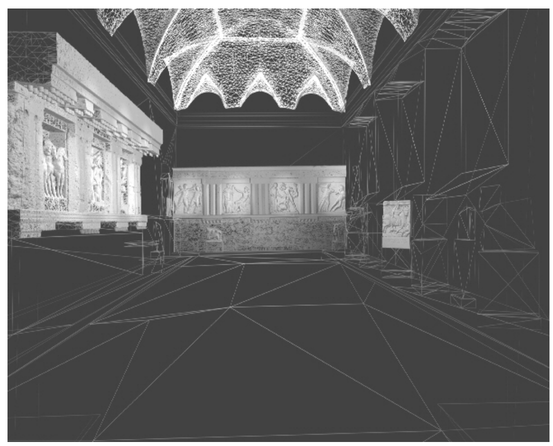


b)

Figure 8. Three-dimensional model of a section of the frieze of Temple C of Selinunte, a) texture-mapped 3D model, b) wire-mesh of 3D model showing the levels of details.

Earlier this year, a video animation was realized. The software 3D Studio Max helped create the 3D animation. The model used for this animation contains 5 million faces, the maximum texture resolution available, 64 lights, and 6700 frames at a resolution of 720×576. This represents an important improvement in terms of resolution compared to the animation Carpiniana that was realized two years ago.

a)



b)

Figure 9. Model of the Museum room, a) Rendering of the complete 3D model of the museum room dedicated to Selinunte, b) wire-mesh showing the multi-resolution 3D model.

6.0 CONCLUSIONS

The potential of modelling *as-built reality* in heritage opens-up applications such as virtual restoration or as an input to virtualized reality tours. As demonstrated with a Byzantine Crypt, a high degree of realism can be attained by those techniques and the context in which the artefacts were discovered or were used can be recreated. Real world acquisition and modeling is now possible. Technological advances are such that difficulties are more of a logistical nature than technological per se. Models of large objects, structures and environments are possible but as demonstrated here require the combination of a number of techniques. The problem we addressed in this paper is the use of 3D modelling to enhance the understanding of a heritage site that needs to be preserved and shown to more people in order to raise awareness and understanding of the Byzantine and the Greek cultures present in Italy. A CDROM, a DVD, a virtual 3-D theatre, a number of holograms and two video animations were created to fulfill these hopes. The work on the re-building of temple C of Selinunte is currently underway and will benefit from the experience gained during the work of the Byzantine Crypt of Santa Cristina.

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REFERENCES

[1] G. Godin et al. "Active Optical 3D Imaging for Heritage Applications," IEEE Computer Graphics and Applications, 22 (5), pp. 24-36, 2002.

[2] M. Soucy, G. Godin, R. Baribeau, F. Blais, M. Rioux, "Sensors and algorithms for the construction of digital 3-D colour models of real objects," Proc. of the IEEE ICIP, V. 2, pp. 409-412, 1996.

[3] F. Bernardini, I.M. Martin, H. Rushmeier, "High-quality texture reconstruction from multiple scans," IEEE Transactions on Visualization and Computer Graphics 7 (4), pp. 318-332, 2001.

[4] J-A Beraldin, M. Picard, S.F. El-Hakim, G. Godin, V. Valzano, A. Bandiera, C. Latouche, "Virtualizing a Byzantine Crypt by Combining High-resolution Textures with Laser Scanner 3D Data," VSMM 2002, 25-27 September 2002, Gyeongju, Korea, pp. 3-14.

[5] S. F. El-Hakim, J.-A. Beraldin, M. Picard, G. Godin, "Detailed 3D Reconstruction of Large-Scale Heritage Sites with Integrated Techniques ," IEEE Computer Graphics and Applications, May/June 2004, 24 (3), pp. 21-29.

[6] P. K. Allen, A. Troccoli, B. Smith, S. Murray, I. Stamos and M. Leordeanu, "New Methods for Digital Modeling of Historic Sites," IEEE Computer Graphics and Applications, Nov./Dec. 2003, pp.32-41.

[7] J. Stumpfel, C. Tchou, N. Yun, P. Martinez, T. Hawkins, A. Jones, B. Emerson, P. Debevec, "Digital Reunification of the Parthenon and its Sculptures," 4th International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage, Brighton, UK, 2003.

[8] F. Blais, "A Review of 20 years of Range Sensor Development," Journal of Electronic Imaging, 13(1), 2004, pp. 231-243.

[9] J.-A. Beraldin, "Integration of Laser Scanning and Close-range Photogrammetry – the Last Decade and Beyond," Proceedings of the XXth ISPRS congress, Commission VII, Istanbul, Turkey, July 12-23 2004, NRC 46567, pp. 972-983.