CARPINIANA: A VIRTUALIZED BYZANTINE CRYPT

V. Valzano[**a], A. Bandiera[a], J-A Beraldin[*b], M. Picard[b], S.F. El-Hakim[b] and G. Godin[b]
[a]SIBA Coordination, University of Lecce, Italy
[b]Institute for Information Technology, National Research Council Canada, Canada

Abstract - This paper presents the 3D modelling work that was accomplished in preparing a multimedia CDROM about the history of a Byzantine Crypt. An effective approach based upon high-resolution photo-realistic texture mapping onto 3D models generated from range images is used to present the spatial information about the Crypt. Usually, this information is presented as 2D images that are flat and don't show the three-dimensionality of an environment. Both a CDROM and a video animation have been created for this project.

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 3D 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. When preparing a multimedia CDROM about the history associated to a particular historical or archaeological site, spatial information is usually presented using 2D images that are flat and don't show the three-dimensionality of that site or environment. An effective approach based upon photo-realistic texture mapping onto 3D models generated from high-resolution range images was used to present that spatial information about a site. The results are applied to the creation of a CDROM about the Byzantine Crypt known as the Crypt of Santa Cristina (see Fig.1), which is located in Carpignano (LE), Italy.

a)

b)

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

USING 3D INFORMATION FOR OUR MULTIMEDIA CDROM

When trying to present 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

** siba@siba2.unile.it; http://siba2.unile.it/
* angelo.beraldin@nrc-cnrc.gc.ca; http://www.vit.iit.nrc.ca/

less reality and 3D 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. We opted to represent our site (a Byzantine Crypt) using both photogrammetic techniques for the outside, and, for the inside dense 3D laser scanner information combined with high-resolution colour images. The Crypt of Santa Cristina was excavated (rupestrian site) at around the 9th century c.e. and it is characterized by two entrances. One of them leads to the area that served as a cemetery and the other, as the church. Furthermore, irregularly shaded walls covered with a number of fairly well preserved frescoes characterize this Crypt. One of them, Christ (Pantocrator) and the Annunciation, is dated at 959 c.e. and is signed by Theophylact. The structure of the image is similar to images of the same period, present in Constantinople and in Cappadocia (Turkey). Mostly experts of the Byzantine period come from around the world to visit and study this site. During the course of history, a Baroque altar was added (1775 c.e.) along with three pillars that replaced one that collapsed. Many aspects of sensing and modeling must be understood before starting such a large project. The typical processing pipeline used for 3D modeling includes geometric modeling and appearance modeling. These are well documented in references [1-6]. Here, we summarize what was done in the case in point. The technical aspects of the project are described in Beraldin et al. [2].

MODELLING TECHNIQUES USED FOR THE BYZANTINE CRYPT

Geometric Modeling

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. Though not as mature as photography, 3D imaging is seeing new applications emerging every year. 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. This range of distances represents the transition between optical triangulation and time of flight technologies. In order to create a dense 3D model of the Byzantine Crypt, a MENSI SOISIC^{TM}-2000 SD 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. The spatial resolution of a model mesh is determined by the angular resolution of the laser inside the scanner. The lowest possible resolution with the Mensi scanner is 0.1 milli-radians. For instance at a distance of 2.5 m (standoff distance selected), this angular resolution corresponds to a spatial resolution of about 0.25 mm. To minimize the amount of time spent in the Crypt, a strategy for scanning was defined well before starting the work. In order to keep a quasi-constant spatial sampling on the surface of the walls, 3D vertical scans were used to build the 3D model. In theory we could have used the lowest angular resolution available with this scanner but in practice, this would have required very long scanning sessions. Therefore, it was decided to increase the sampling step on the mesh to 5 mm. This gave an average scan time per 3D image of about 80 minutes. As a result, surface details like small tool marks were not measured well at that resolution but the overall shape of the Crypt is excellent. Figure 2 present the complete 3D model (without color 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 both the camera manufacturer's own software 3DipsosTM and PolyworksTM software from Innovmetric. The actual measurement uncertainty was found to be twice the value given for cooperative surfaces, i.e. 0.8 mm at a distance of 2.5 m.

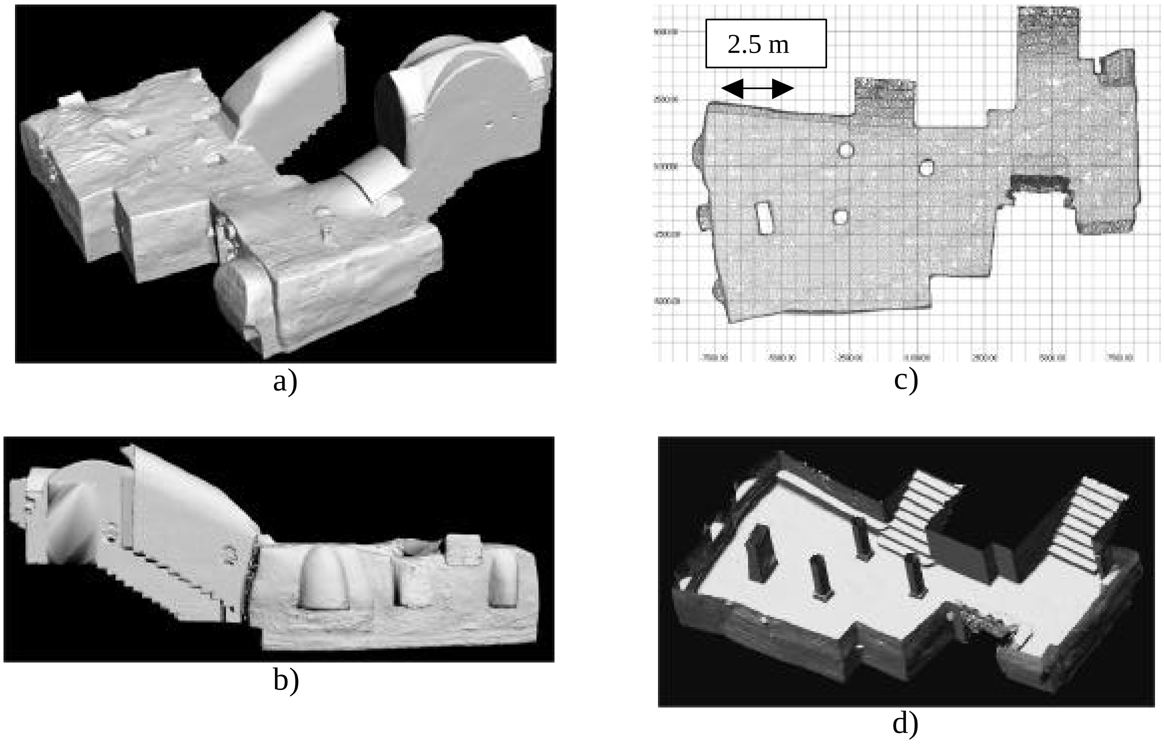


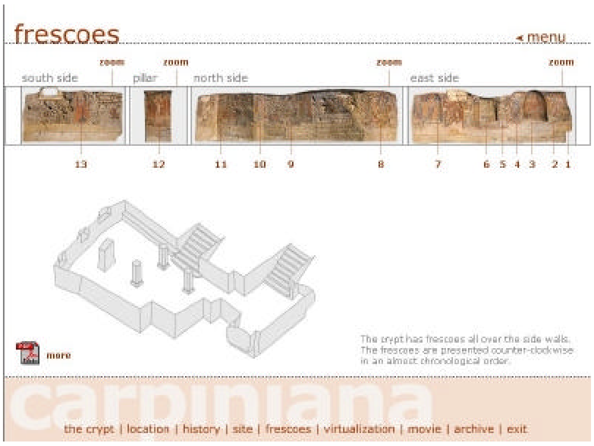
Figure 2. Complete 3D model of the Byzantine Crypt, a) view from outside shown with synthetic shading, b) a particular view of the stairs leading to the Crypt, c) floor plan generated from an orthographic view of the 3D model, d) section of 3D model showing the space inside the crypt.

Appearance (Color Texture)

Appearance modeling includes methods like Image Perspective Techniques (IPT) and Reflectance Modeling (RM). IPT is concerned with direct mapping of photographs onto a 3D model and reflectance modeling [4-7]. Reflectance modeling is used to extract from the measured colour and shape those physical properties of an object that are intrinsic to it and that determine its appearance when viewed with artificial lighting on a computer screen [3]. 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 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. Flashtubes with a colour temperature of about 5600 K were used to acquire textures.

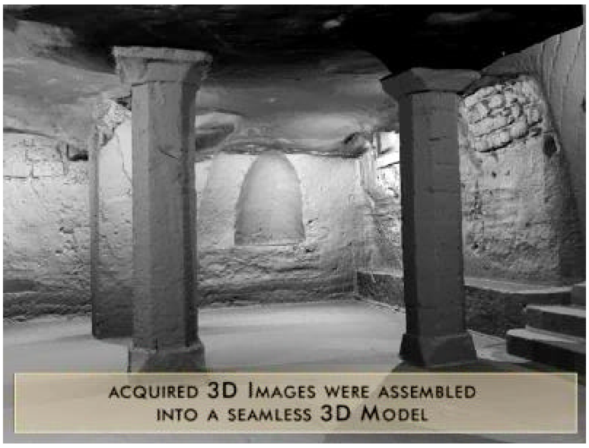
CDROM AND VIDEO ANIMATION: *CARPINIANA*

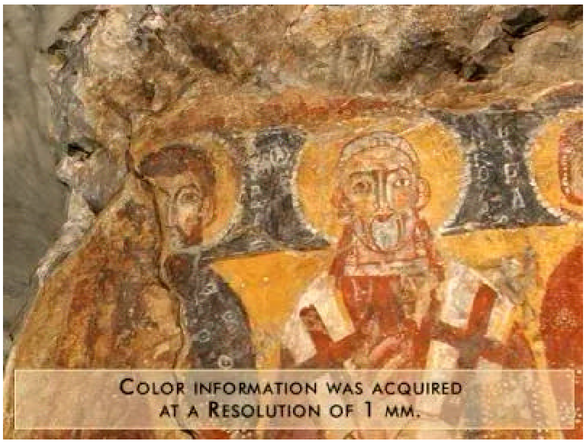
Realistic estimate of the time to acquire the range images, build a 3D model and the determination of the required quality of model is very critical for such a project. For this site, with an average scan time on the walls of 80 minutes per 3D image, a total of 92 hours were spent in the Crypt. During 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) b)

Figure 3 CDROM: a) entrance page, b) use of orthophotos generated from 3D model to navigate through the frescoes.





a) b)

Figure 4 Movie: a) view of crypt without texture, b) view of main pillar with texture.

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 artifact 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 Figures Figure 3 and Figure 4 respectively.

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 period. Both a CDROM and a video animation were created to fulfill these hopes.

ACKNOWLEDGEMENTS

Contributors: E. Bandiera, F. Bergamo, M.C. Catamo, Sac. G. Colavero, D. Lucarella, R. Ingrosso, A. Marra, F. Melcarne, S. Nuccio, P. Pulli, A. Van Den Troost, U. Parrini, M. Biliotti, C. Sempi, V. Blasi, R. De Rinaldis and M. L. Blasi. Co-financing was provided by the Ministero dell'Istruzione, dell'Università e della Ricerca and the European Union (F.E.S.R.) for initiative 18 of the Piano Coordinato delle Università di Catania e Lecce.

REFERENCES

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

[2] 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.

[3] 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.

[4] 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.

[5] S.F. El-Hakim, C. Brenner, G. Roth, "A multi-sensor approach to creating accurate virtual environments", *ISPRS Journal of Photogrammetry & Remote Sensing* **53**, pp. 379–391, 1998.

[6] V. Sequeira, K. Ng, E. Wolfart, J. Goncalves, D. Hogg, "Automated reconstruction of 3D models from real environments", *ISPRS Journal of Photogrammetry & Remote Sensing* **54**, pp. 1-22, 1999.

[7] M. Weinhaus, V. Devarjan, "Texture mapping 3D models of real-world scenes", *ACM Computing Survey* **29** (**4**), pp. 325-365, 1997.