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Realistic Representations of Cultural Heritage Sites and Objects through Laser Scanner Information

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When presenting the history of a heritage site or an artefact using multimedia technology, the proper use of technology to acquire and represent spatial information is crucial in order to facilitate the understanding of that particular site and the relationship between the elements constituting that site. In many cases, one has to model complex environments that have a rich historical content. These are composed of several objects with various characteristics and it is essential to combine data from different sensors and information from different sources. There is no single approach that works for all types of environment and at the same time is fully automated and satisfies the requirements of every application. A general approach combines information from historical material, multiple images, single images, laser scanner data, known shapes, CAD drawings, existing maps, survey data, and GPS data. This paper presents the work that was accomplished in preparing realistic representations of cultural heritage sites for interpretation and entertainment purposes. The general approach was applied to three cases: the Byzantine Crypt of Santa Cristina, Apulia; the remains of Temple C of Selinunte Sicily; a bronze sculpture with very fine incisions, and, a cave with Neolithic paintings.

Introduction

General

The use of technology to properly acquire and represent spatial information is central to a strategy that wants to facilitate the understanding of a particular historical site and furthermore aims at showing the relationship between the elements constituting that site. In many cases, one has to model complex environments that are usually composed of several objects with various characteristics. To achieve this goal, it is essential to combine data from different sensors and information from different sources. There is no single approach that works for all types of environment and at the same time is fully automated and satisfies the requirements of every application. A general approach based on sensor fusion techniques combines models created from multiple images, single images, range sensors, known shapes, CAD drawings, existing maps, survey data, and GPS data (EL-HAKIM et al., 2005). The main objective of the fusion is to minimize the impact of uncertainties and augment the amount of information available on a site in order to get the most out of the multi-sensor platform.

Sites description

Two sites presented here are aimed at the general public and to a certain degree to the expert. To achieve these goals, the integration of both photogrammetric and CAD modelling was used to complement the approach presented above. The first site is the Byzantine Crypt known as the Crypt of

Santa Cristina, which is located in Carpignano (LE), Italy. Results on a CDROM, a DVD, virtual 3-D theatre, holograms and video animations have been prepared for this project. Some of these results are shown in Section 2. The second site is Temple C of Selinunte, Sicily. For the acquisition of 3D information, both laser scanning and digital photographs using a calibrated camera/lens were used. Three-dimensional modelling was performed using two different 3D laser scanners, photogrammetry and CAD. At the moment, the museum room containing artefacts from the site in Selinunte was modelled using a mixture of the above-mentioned technologies. A CAD reconstruction from historical information of temple C of the Acropolis of Selinunte was prepared by a different work group. A CDROM is being prepared for Temple C. Section 3 presents more details about the reconstruction process. The third example which is described in Section 4 pertains to the modelling of a bronze sculpture known as the Zeus of Ugento, Italy (now part of the collection at the museum of Taranto, Italy). The sculpture measures about 71.5 cm (height) × 45 cm (hand-to-hand) × 18 cm (back-to-torso). The surface around the head is characterized by fine incisions and decorations. A high-resolution 3D model (without colour) was acquired with a high-resolution laser scanner in order to target the expert user. Here, accuracy is of utmost importance. Section 5 will describe briefly an ambitious collaborative project started in February 2005. It aims at modelling a cave with Neolithic paintings composed of three main corridors. Work on one corridor measuring about 300 m is underway. This paper ends with some concluding remarks about the potential of modelling as-built reality using the fusion of 3D data obtained from complementary techniques.

Virtualizing a Byzantine Crypt

Modelling techniques used for the project

We opted to represent the Byzantine Crypt of Santa Cristina (Carpiniana project) using both photogrammetric techniques for the outside (using ShapeCaptureTM software), and, for the inside dense 3D laser scanner information combined with high-resolution colour images (Fig.1). 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 3D 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. Here, we summarize the results of the virtualization of the Byzantine Crypt. The detailed technical aspects of the project are described in BERALDIN et al., 2005.

CDROM and Video Animation: Carpiniana

We are currently working with three 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 into orthophotos (Fig. 2), isometric cross-sections and smaller 3D models in order to navigate through the information on the CDROM. All of these representations are aimed at showing the three-dimensionality of the site that is 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 Fig 3. When the animation was realized, i.e. year 2002, the computing power was not sufficient to deal with the high-resolution model. The software 3DStudioMaxTM helped create the animation. The model used contains 400 000 triangles, 1/5 of the maximum texture resolution, 13 lights, 5000 frames at a 720 × 576 resolution. Today, the full resolution (shape & texture) could 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 allows for a real-time navigation inside the Crypt for further study. A few large format holograms (1.8 m × 0.85 m) were also produced from the digital 3D model.

Temple C of Selinunte

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 photogrammetry and CAD tools. The 3D model will be based on historical information available at the University of Lecce and at the "Museo Archeologico Regionale" of Palermo, Sicily. In the first step, scanning and modelling of three Metopes from the temple were done in the regional museum of archaeology of Palermo, Italy (Fig. 5a).

Practical considerations

A visit to the museum and to the site allowed the team to plan the activities. One of the main concerns was the determination of the required spatial resolution and the technical difficulties the team might encounter. The spatial resolution depends on the level of details desired by the project but also by the equipment available and practicality of the choice (BERALDIN et al., 2005). The spatial resolution picked for merging the 3D images together determines the size of the smallest triangle on the mesh. Other issues can come from the hidden surfaces hard to reach areas and vibrations induced when scaffoldings are used. Both scaffoldings and a mirror placed in the path of the laser beam were used to reach some of those 3D surfaces (Fig. 4).

The three Metopes of Temple C

The 3D model of the frieze from Temple C including the three Metopes is shown on Fig. 7. We continued the laser scanning work using both the Minolta 900 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 while the second scanner (Mensi SOISIC-2000) 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. The 3D model of the frieze generated by laser scanning was registered to the frieze created by photogrammetry-based 3D modelling. A rendering of the complete museum room dedicated to Selinunte is shown on Fig. 5b. Later this year, the work described above will be integrated with the virtual reconstruction of Temple C. A video animation was realized earlier this year using the software 3DStudioMax^{TM}. The model used for this animation contains 5 million triangles, 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 Carpiniana that was realized in 2002.

Museum room in Palermo

The first part of this project started with the modelling of the frieze of temple C of Selinunte using 3D laser scanning. Later, the second step will see the reconstruction of temple C of the Acropolis of Selinunte using photogrammetry and CAD tools. While at the museum (Fig. 5a), it was decided to model the room where the artefacts from different temples from Selinunte are exposed. A rendering of the virtualized room that measures about 21 m × 8.1 m × 7 m is shown on Fig. 5b; the wire-mesh representation is shown on Fig. 6. In order to achieve a high degree of realism and accuracy, 3D laser scanning, photogrammetry, CAD and texture processing were used. The quality of the textures was realized using high quality flash lamps, a MacBeth chart and Photoshop. The grey scale available of that chart was used to correct the gamma of the camera and the different levels of illumination. A five-point correction method was used. One of the Metope is shown on Fig. 8. A 3D video animation was created to complement a documentary about the work and the history of temple C (Fig. 9).

Zeus of Ugento (6th Century BC)

This project stated with the creation of a high-resolution 3D model of the bronze statue. Bronze, which is used frequently for statues, presents a number of challenges to the 3D photographer. The material is fairly specular even if the statue is more than 2500 years old! The surface is dark looking but when a light source is shone on it, both diffuse and specular components appear. Dark surface mean that the signal-to-noise ratio drops and hence the measurement uncertainty goes up. At a specular reflection, the range camera goes in quasi saturation and sometimes in full saturation. When in quasi-saturation, the range data looks good but in reality the uncertainty increase enough to render the model of lesser quality. It was decided to use a laser scanner to model the statue as opposed to using a fringe projection system. The spatial resolution depends on the quality of laser (tight focusing) used in the scanner. A number of tests were conducted to determine the best system to measure the surface of this bronze statue. Fig. 10 shows the results obtained from the two contenders picked for this work. Fig. 10a and b present a shaded view of the partial beard area (25 mm × 25 mm) for systems Minolta 900-tele lens and ShapeGrabber SG-102 respectively. After a number of tests, it was decide to use the ShapeGrabber SG-102 system to model the complete sculpture. During the course of the 3D acquisition, the accuracy of the scanner (Fig. 11a) and of the 3D model were verified against accurate reference objects (Fig. 11).That system could have been used on the Metope but it was considered a bit cumbersome to use on scaffoldings. The final model was prepared with about 175 3D images with an average mesh resolution of 0.2 mm. shows two views of the model using synthetic shading (Fig.

12). The colour has not been acquired for this application. The results of this work will be integrated with historical information already available on this unique work of art into a CDROM.

Cave with Neolithic paintings: *Grotta dei Cervi*, Italy

We describe briefly an ambitious collaborative project started in February 2005. The project aims at modelling a cave with Neolithic paintings known as *Grotta dei Cervi* that is composed of three main corridors. The main motivation comes from the fact that the cave is closed to the general public and that only a limited number of experts are allowed in every year. This measure is necessary in order to preserve the delicate environmental balance inside the site. Unfortunately, because the cave was discovered recently (1970) and the limited access, very little information is available to everyone. Here a detailed 3D model would allow for a better understanding, increased information and virtual visits of the site without traumatic consequences to it. Work on one corridor measuring about 300 m is underway. Figure 13 shows a photograph of a team member during the preparation tasks before of the start of the project. More information will be available as the work progresses.

Conclusion

The potential of modelling as-built heritage objects and sites opens-up promising applications such as 3D documentation, 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 modelling 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. More research work is required to speed up the process of acquisition and modelling. These steps still require a larger amount of time.

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 southern Italy. A CDROM, a DVD, a virtual 3D theatre, a number of holograms and two video animations were created to fulfil these hopes. The work on a cave with Neolithic paintings is currently underway.

Acknowledgements

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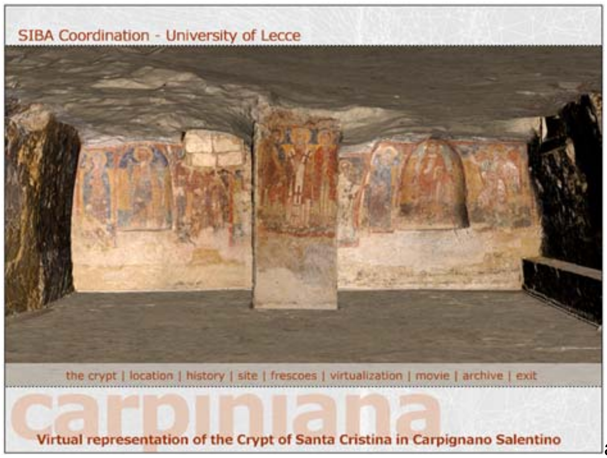
a) b)

Fig. 1. Section showing Christ Pantocrator, a) coloured 3D model illuminated by one source of light, b) close-up showing the wire-mesh on which the colour was mapped (the smallest triangle have sides of about 5 mm).

Fig. 2 - Ortho-photo of a full wall of The Byzantine Crypt of Santa Cristina, Apulia, Italy: top: shaded, bottom: coloured.



a
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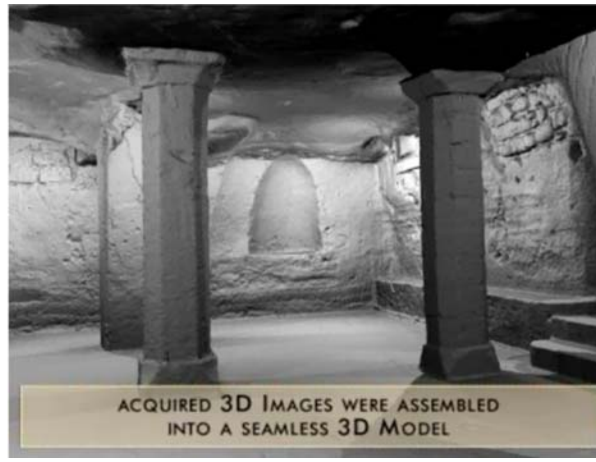


b
)

Fig. 3 - The Byzantine Crypt of Santa Cristina, Apulia, Italy: a) entrance page of the CDROM CARPINIANA, b) still image taken from the movie included on the CDROM & DVD: view of crypt without texture. In the video animation, the colour information is introduced half way in the movie.


a)


b)

Fig. 4 - Practical considerations when using a 3D scanner: mirror used to reach hidden 3D surfaces.


a)


b)

Fig. 5 - Virtualized Museum room, a) photograph of the room dedicated to Selinunte of Palermo, Sicily (Museo Archeologico Regionale), b) rendering of the complete 3D model of the same museum room.

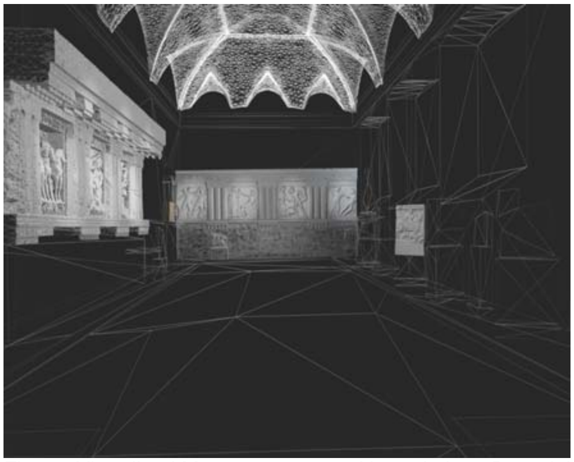


Fig. 6 - Virtualized Museum room: multi-resolution 3D model shown as a wire-mesh model.


a)


b)

Fig. 7 - 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.


a)

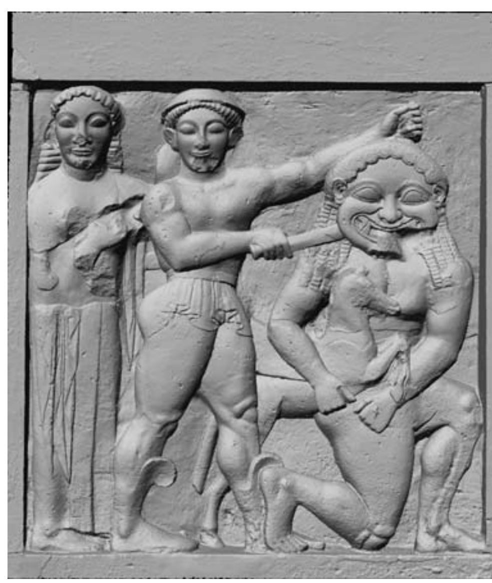
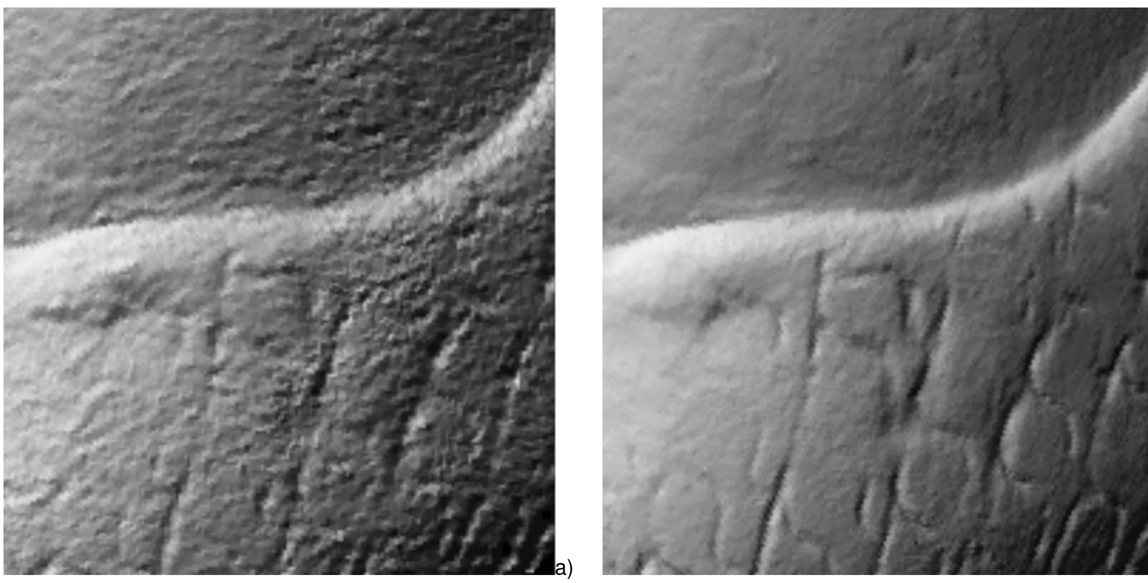

b)

Fig. 8 - Three-dimensional model of a Metope of Temple C of Selinunte, a) texture-mapped 3D model, b) shaded 3D model.

Fig. 9 – Selinunte: Frame taken from the 3D video animation.



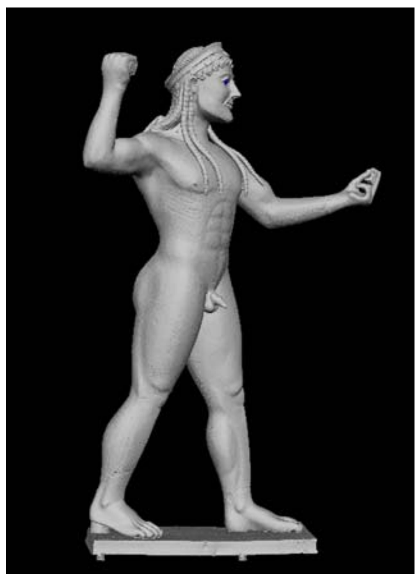
a) b)

Fig. 10 - Close-ups (~ 25 mm × 25mm), a) shaded view created from the 3D data acquired with a Minolta 900 (tele-lens), b) shaded view created from the 3D data acquired with a ShapeGrabber SG-102 head mounted on a translation stage.


a)

b)

Fig. 11 – Accuracy verification: a) laser scanner intrinsic and extrinsic calibration b) stadia bars used to check the 3D model.


a)

b)

c)

Fig. 12 - Final 3D model of Zeus of Ugento showed using synthetic shadings (colour information has been removed to reveal the surface details), a) photograph, b) frontal view, c) back view.

Fig. 13 – Neolithic cave - *Grotta dei Cervi*, Italy. Photograph showing a team member during the preparation work before the actual 3D modelling work.