

INNOVATIVE TECHNIQUES FOR SURVEY AND COMMUNICATION OF CULTURAL HERITAGE

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ABSTRACT:

This paper deals with the survey and communications of Cultural Heritage through the development of innovative methodologies. The case of study is the polychrome wooden ceiling in the “Magna” Hall of “Palazzo Steri”. The “Steri”, built in the XIVth century by the noble family Chiaromonte, is at the present the headquarter of the Rector’s Office of Palermo University. A 3D model of the wooden ceiling has initially been carried out with laser-scanning and digital photogrammetric techniques; successively a multimodal interactive guide has been realized. The guide is integrated to the 3D model, so that visitors can navigate the virtual representation of the ancient wood ceiling and achieve, interacting vocally, relevant meta information about history and sense of painted scenes.

1. INTRODUCTION

In the last years the development of electronics and informatics has opened new scenarios of research in the field of survey, representation and communication of Cultural Heritage. 3D virtual model of an artefact today can be easily obtained using the high level of automation achieved in survey works; however, for an overall documentation, an integration among different surveying methods is desirable. The integration between laser scanning and digital photogrammetric techniques, the combined use of different laser scanners, in relation to the complexity and the detail level to achieve, seem the right way to get good results.

In regard to the aspect of Cultural Heritage fruition, recent studies in the field of artificial intelligence and human-computer interaction have developed systems that can interact with the user in a variety of modes and in the most natural way; with the use of these systems it is possible to generate, navigate and explore reconstructed environments of cultural interest, enabling the extended fruition of works of art which are not physically accessible to the user.

2. HISTORICAL NOTES

The Steri Palace in Palermo, residence of the Chiaromonte family, was built starting from 1320 on the eastern edge of Piazza Marina, near the city’s ancient harbour (Figure 1).

The Chiaromonte family was chased away from the palace in 1392, and in the two following centuries the Steri was a royal and vice-royal residence. From 1605 to 1782, the Palace was

the headquarters of the Inquisition Tribunal, a place of detention and torture. There is little evidence left of that long period due to the fire that destroyed the documents of the tribunal’s archive. Graffitos, paintings and verses carved by prisoners on the cell walls have remained. These documents were discovered in 1906 during some restoration works, followed by the careful and patient transcription and interpretation work by Giuseppe Pitrè. During more recent restoration works, further paintings have been found in some buildings near the Steri Palace.

Since 1984 the Steri has been the headquarter of the Rector’s Office of Palermo University, that has commissioned the restoration works which have given the building its current feature.

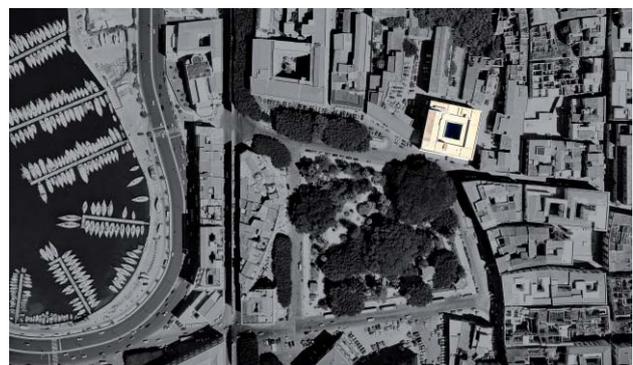


Figure 1. Ortophoto of Piazza Marina; in evidence: the Steri Palace.

The Steri is a parallelepiped block with few holes to the outside and a large inner court with a two-level arcaded loggia. The

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“Magna” Hall has a rectangular shape, and its average size is : 8.35m x 27.50m. It is sited at the Northern side of the building’s first level and was the most important room of the palace, used for public events (Figure 2).

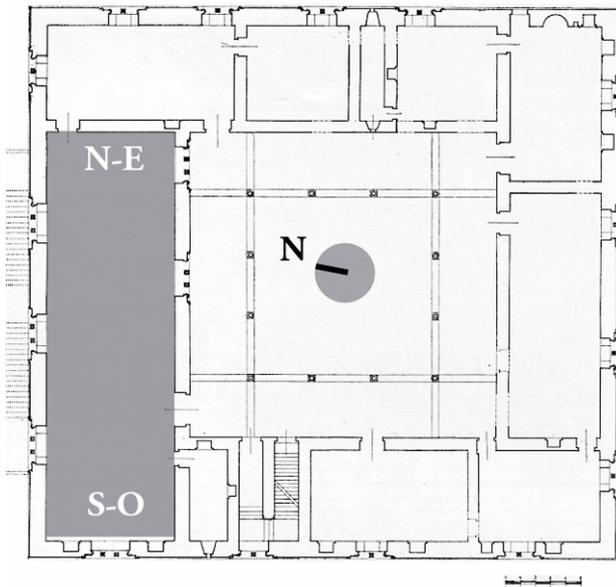


Figure 2. Plan of the first level of the Steri

The wooden ceiling covering the Hall is made of twenty-four beams laid transversally, and lacunars covering the empty space between the beams. The beams are fitted to the walls and laid on consoles (Figure 3).

Some inscriptions in gothic characters report the dates of beginning and end of the decoration works, and the names of the painters (Figure 4).

The paintings are made on wooden panels hooked to the vertical and horizontal faces of the beams; the bearing consoles are hidden by false painted consoles which remind, both in geometry and structure, the ruled surfaces of the “muqarnas” in the wooden ceiling of the Palace Chapel in Palermo.

Some paintings have geometric and floral patterns, whilst others portray scenes inspired to religious, mythological and heroic episodes.



Figure 3. The wooden ceiling of the “Magna” Hall.

Scenes related to the same subject are developed on vertical beam faces, all heading to the same direction, in a sequence that

goes, according to the point of view, from left to right, and from the background to the foreground. The partitioning of the panels of each beam was determined by the articulation of the narration into distinct scenes, according to a technique resembling strip cartoons. As an example, one can observe the paintings related to some episodes of the Trojan cycle, on the vertical faces of beams VIII and IX, heading towards the South-Western wall.



Figure 4. Inscriptions in gothic characters.

Each of the right and left portions of beam VIII are subdivided into three scenes, whilst the faces of beam IX are divided in two; the narration is thus articulated in ten scenes.

3. SURVEYING OPERATIONS

Metric data were acquired with direct, topographic, photogrammetric, and laser scanning methods¹. The surveying of some consoles, located in a part of the ceiling reachable with scaffolding, was performed with direct methods.

The topographic survey, performed with a Leica TCR 1105 total station, was used for different purposes: general dimensioning of the ceiling and survey of the hall; measurement of control points for photogrammetric restitution; measurement of targets used for registration and orientation of point clouds. In the first stage of the topographic survey, the tern of axes used as a reference for all data acquired was defined; the adoption of a single reference system made it possible to integrate laser scans performed at different times and with different tools.

Photogrammetric surveying was aimed at producing rectified images of the vertical and horizontal faces of the beams, and of an orthophoto of the whole ceiling. Zenithal photos for the horizontal faces of all beams, and inclined photos for the vertical faces and the false consoles were taken with a Canon EOS mark II digital camera, equipped with a full-format 16.1 megapixel CCD sensor and a 50 mm depth of focus. More than 200 photos were acquired. The digital rectified images of the beams’ faces were obtained using control points measured with

¹ The survey was performed in the framework of an agreement between the Regional Institute for the Catalogue and Documentation of Cultural Heritage, the University of Palermo and the Department of Representation. The instruments used were made available by the “Lab for management and enjoyment of cultural heritage with advanced IT” belonging to Palermo University Lab System (UniNetLab).

topographic survey. The coordinates of such points were transformed to refer their values to the mean plan of each face of the beam. The rectified images were used in the mapping process of the 3-D model (Figure 5).

Laser scans were used for the acquisition of a remarkable number of 3-D points of the ceiling. The scanning operations were conditioned by the complex geometry of the ceiling. In order to reduce the holes corresponding to areas not reached by the laser ray, numerous scans were performed from different points inside the hall.

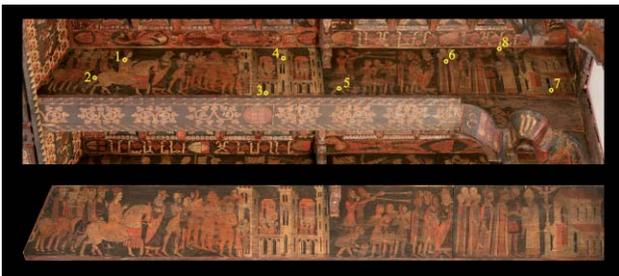


Figure 5. Control points and rectified images of the vertical face of a beam .

In the first stage of the survey, eight scans of the ceiling were performed with a Mensi GS200 scanner equipped with a 2 Megapixel resolution inner digital camera. Due to the low resolution of the integrated camera and to the distance between the scanner and the ceiling, the images acquired have produced a low detailed distribution of radiometric values.

Further scans of the ceiling and the hall were performed with a Faro LS880 scanner, positioned in three different points of the hall in order to obtain a good coverage of the visible areas of the ceiling. The reflectance value was associated to each point measured.

The reference of the point clouds' coordinates to the topographic reference system allowed to integrate the data acquired with the two different scanners.

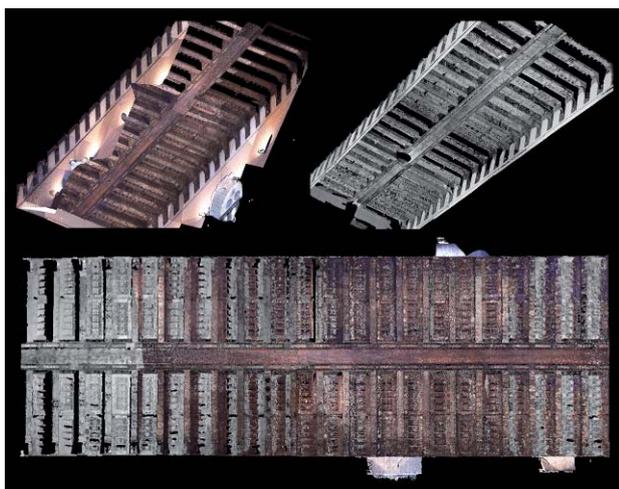


Figure 6. Point clouds of the ceiling.

At the end of the first processing phase of laser data a 15-million-point cloud was obtained for the ceiling and a 3-million-point cloud for the hall (Figure 6).

4. DATA PROCESSING

A first digital model of the ceiling was obtained from the laser point cloud through the automatic extraction of a triangular-mesh. The distribution of triangles, conditioned by the step adopted in the scanning process, results quite homogeneous. Therefore, it happens that a plain surface is described with the same triangle density of a complex surface. This generates a model that is too detailed for simple geometry surfaces, and at the same time inadequate for the description of complex surfaces. The number of triangles of the mesh extracted automatically is approximately double than the number of points in the cloud: this involves, for clouds of million points, computational difficulties in visualization and in processing. The solutions proposed by computer-graphics researchers currently aim at defining new algorithms that permit to manage large amounts of data; this process is presumably going to provide effective solutions.

An alternative solution aims at an 'intelligent' reduction in the number of polygons, detecting discrete sets related to a single element. In this work, for instance, each face of a beam was substituted with the plane that best approximates the corresponding portion of the point cloud. Of course, this process involves a loss in definition, since it can be easily noticed that the faces of the beams are not flat.(Figure 7).

The simplification of acquired data needs to be carefully performed, according to the information that we intend to acquire and convey by means of measurement and interpretation. If, for instance, the work were finalized at relating the distortion of the panels to their position inside the hall, the approximation proposed above would be totally unacceptable. Instead, it is compatible with an activity aimed at defining a single digital representation of the ceiling with its painted decorations.

The modelling of beams and lacunars was performed in two steps: extraction of plans and sections from the point clouds; surface processing and joining (Figure 8). Laser data processing and plane extraction was performed with Rapidform 2006 by Inus Technology; digital modelling was performed with Rhinoceros R 4.0. A similar process was used for the false consoles.

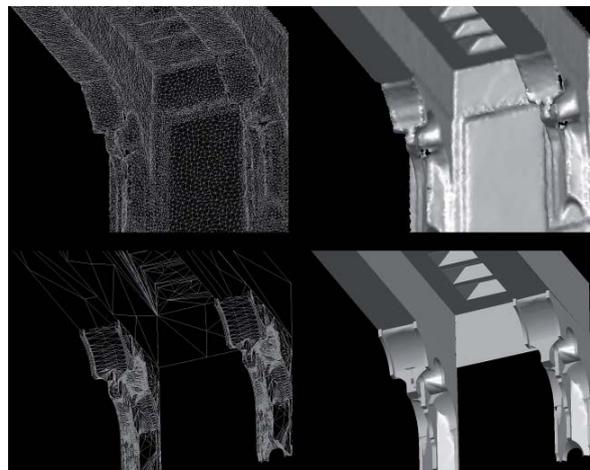


Figure 7. Triangle distribution in laser data (above) and in 3d models.

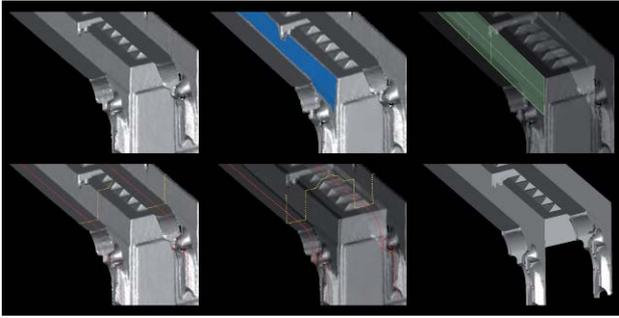


Figure 8. Planes and plane sections from laser data.

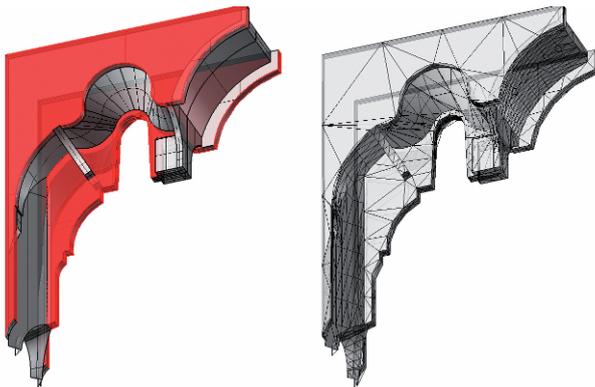


Figure 9. Digital model of a false console.

The process finalized at the use of the CAD models for visualization, rendering, or prototyping, requires a reversion of the digital model into a triangular mesh. The result of this process is a new mesh, where the distribution of the triangles is linked to the shape of the surfaces, different from the mesh automatically generated from the point cloud. (Figure 9).

5. VISUALIZATION

The research on new forms of enjoyment of cultural heritage has set off 'mapping' the three-dimensional model.

In the "Magna" hall, the paintings are not less important than the elements defining structure and morphology of the ceiling; for this reason the mapping process was cared not less than surveying and modelling.

Rectified images were used for mapping beams and lacunars; convergent photographic takings were used for false consoles. The mapping process, which consists in assigning the raster image UVW coordinates linked to the XYZ coordinates of the model, was relatively easy for the plane faces of beams, where just a dimensional and position adjustment was needed (Figure 10). The mapping of false consoles was more complex and harder, since it was necessary to proceed by trial and testing; the quality of this mapping is therefore directly related to the sensitivity and skill of the operator.

The 3-D model thus obtained allows to observe the paintings in their spatial collocation; it gathers what has always been distinguished in literature, i.e. paintings – described with photos – and the physical support - described by graphic or physical models.

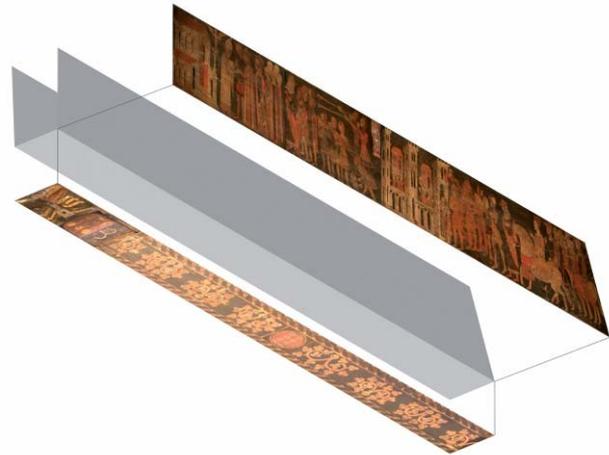


Figure 10. Plane faces mapping process.

The transformation of the model into a generic format for visualization (VRML) makes 3D exploration accessible also to users who do not have specific software, and who are not familiar with the CAD environment. In this format, access to the model can also occur via internet, and allow users and scholars from distant Countries to tour the "Magna" Hall.



Figure 11. Views of the texturized model.

6. THE MULTIMODAL GUIDE

The use of virtuality and multimodality, in Cultural Heritage fruition, allows for a solution to the contrast between the conservative and expositive function of the cultural heritage. This approach gives a trade-off between the need to preserve unchanged the authenticity of the deteriorated heritage and the demand to aesthetically make it comprehensible and enjoyable. The system embed the virtual environment with a multimodal interactive guide which assists the user during his virtual tour. Visitors can navigate the virtual representation of the ancient wood ceiling with tempera paintings and achieve, interacting vocally, relevant meta information about history and background of painted scenes.

The implemented prototype aims at assisting a user during a visit of two rafters of the ceiling that report scenes of the Trojan Cycle. Furthermore, as the painted scenes follow a logical path according to the story of the Trojan Cycle, a visitor would better enjoy its sight if supported by a detailed description of the scenes and their related background.

To create an appropriate dialogue the information about the context has been extracted and translated in English from historical source material and stored in a database.

As shown in Figure 12, historical information about the paintings have been divided in: scene description, character genealogy and background that is referred to a scene as prior events and/or to characters as flashback.

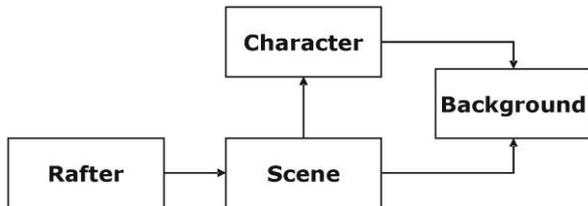


Figure 12. Formalization of context information.

Interface features have been decided by evaluating possible visit scenarios, assuming the virtual representation as a way to augment visitor experience on site.

In Figure 13 the logical flow of the application navigation is shown. The interaction is centered on the rafters. The user can visit the room and select a specific rafter to look in detail. Specific scenes of the rafter can be visualized, and historical/artistic voice-over be heard at the same time. At any time during the visit, a visitor can change viewpoint, leaving him to explore the virtual environment according to his preferences.

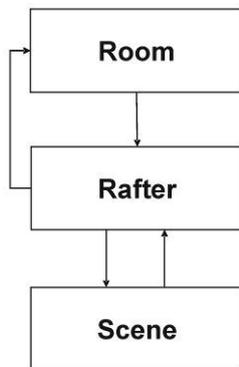


Figure 13. Interaction's logical flow

The initial screen of the application represents the entire room. It is possible to navigate inside the room with the functionalities made available by the X3D player. A welcome message introduces the visitor to the availability of a vocal guide, and gives some preliminary information on how to interact with the system.

During navigation, when rafters are in sight, some tooltips, shortly describing the content of each rafter, guide the visitor through the tour. When the user selects a rafter, the point of view changes showing all the scenes in the rafter, while the vocal guide gives some information to the user as shows in Scheme 1.

System: You are looking at rafters eight and nine, showing the Trojan Cycle. Click on the scene to zoom in and to listen more.
User: (Click on the scene: "Report of Paride").

Scheme 1. Dialogue interaction in rafter view.

In this view, the various scenes about the Trojan Cycle are shown to the user and each one can be selected to access more details. Once a scene is chosen, it will be zoomed in, the multimodal guide will be activated, and the historical/artistic information will be delivered. The guide will prompt the visitor to solicit interaction for further details, as described in sample dialogues in Schemes 2 and 3, where the visitor may be querying about a scene or access information about its characters. Narration can be skipped at any time.

System: You are looking the scene called Report of Paride. Do you like to listen some detail about this scene?
User: Yes.
System: In this scene Paride narrates the judgment to Priamo and Trojan nobility, which is a preview of a following scene. Are you interested in more details about characters story or background of the scene?
User: Yes, thanks.

Scheme 2. Dialogue in the scene perspective.

System: Which characters are you interested in?
User: Help.
System: Say the name of the character, choosing between Paride Priamo Elena.
User: Paride.
System: In Greek mythology, Paride was the child of Priamo and Ecuba; just before his birth, his mother dreamed that she would give birth to a flaming torch
User: Skip.
System: Are you interested in another character?
User: No.
System: Great, let's move to the next scene.

Scheme 3. Dialogue about details of the scene.

The figure 14 shows a screenshot of the application, accessed on the first scene about the Trojan Cycle. The screenshot shows also the guide window in foreground. At all times, this windows can be hidden, moved or resized, according to the scene elements.

Work are in progress to enable voice navigation of the virtual environment. Using his/her voice, the user would issue commands for simulated flight or "teleportation" to arbitrary locations without the need to navigate step-by-step, find entities in a large 3D space, etc.

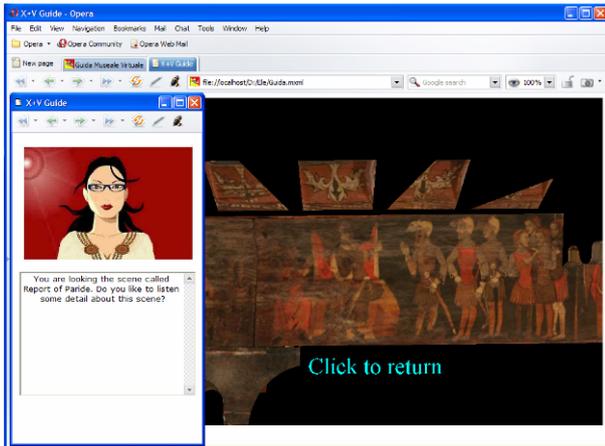


Figure 14. Application screenshot.

7. CONCLUSIONS

The work reported in this paper is a part of a wider investigation on a procedure for the integration of laser data with CAD models and photogrammetric data. Procedures for the production of 3D orthophotos and photorealistic 3D models have been performed using commercial photogrammetric packages. Further investigations have been addressed to define a digital work that combines easy visualization with a multimodal guide to the history and the symbolic contents of the cultural heritage.

REFERENCES

- Alshawabkeh, Y., Haala, N., 2005. Automatic multi-image photo-texturing of complex 3D scenes. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science*, Volume XXXVI-5/C34, pp. 68-73.
- Beraldin, J.A., Picard, M., El Hakim, S.F., Godin, G., Latouche, C., Valzano, V., Bandiera, A., 2002. Exploring a Byzantine crypt through a high-resolution texture mapped 3D model:

combining range data and photogrammetry. *Proceedings of the CIPA WG6 International Workshop on Scanning for Cultural Heritage Recording*, Corfù, Greece, 1-2 September 2002, pp. 65-72.

Böhm, J., 2004. Multi-image fusion for occlusion-free façade texturing. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science*, Volume XXXV-5, pp. 867-872.

Bologna F., 2002. *Il soffitto della Sala Magna allo Steri di Palermo*, edited by Flaccovio, Palermo (Italy).

Trumello E., Santangelo A., Gentile A., Gaglio S. (2008). A Multimodal Guide for Virtual 3D Models of Cultural Heritage Artifacts. *Proceeding of the first International Workshop on Intelligent Interfaces for Human-Computer Interaction (IIHCI)*, Barcellona, March 4-7, pp. 735-740.

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