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SURVEYING, MODELING AND COMMUNICATION TECHNIQUES FOR THE DOCUMENTATION OF MEDIEVAL WOODEN PAINTED CEILINGS IN THE MEDITERRANEAN AREA

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ABSTRACT:

Wooden painted ceilings of the Mediterranean area in the middle age have their origin in the islamic culture and were then spread in the countries under the dominion of the Arabs; some of the surviving ceilings are now located in Sicily and Spain. In the historic centre of Palermo two well preserved medieval ceilings are still surviving; the first, built in the XII century, is located in the Palatine chapel; the second one, built in the XIV century covers the “Sala Magna” in the Steri of Palermo.
The research, focused on the ceiling in the Steri, deals with the definition of a process for the integration of surveying techniques (photogrammetry, laser scanning), modelling processes and communication technologies for the documentation of such artefacts.
The documentation of painted ceilings requires the strict integration of photographic and 3D metric data; the existing documentation is usually made of documents (drawings, photographs) that keep geometric and metric data separated from the photographic documentation of the paintings.
The first stage in this work is therefore addressed to produce a digital document that combines metric and photographic data in a 3D textured model; in the second stage a vocal guide interacting with the 3D model has been developed; such guide, thought as a support to people visiting the Steri, uses a database with historic contents and symbolic interpretation of the painted scenes to answer specific questions and “take” the visitor close to the related paintings.

1.INTRODUCTION

The high level of automation achieved in the survey operations and the possibility of managing, through the use of dedicated software, a lot of information offer today new opportunities within the field of conservation and communication of Cultural Heritage but at the same time have introduced new problems. An important aspect, object of great interest by the international scientific community, concerns with the communication between the responsibles for data acquisition, elaboration and management (surveyors, photogrammetrists, GIS operators) and the users of information (archaeologists, historians, experts in the field of restoration).
The paper deals with the study of the problems related to the survey and communication of Cultural Heritage through the various phases, from data acquisition and processing to data management. The experiences gained in this field have always shown more and more attention of the experts and historians towards new technologies; however the access difficulty to information often interferes with this interest. Today the automatic acquisition of geometrical data, the attribution of space data and the management of all information concerning an artefact by a single tool, are indispensable components both for data documentation and communication.
The research work is organized into two stages. In the first stage different techniques of survey have been tested and the problems related to the integration of data acquired have been studied. The definition of an homogeneous datum able to describe the geometrical and qualitative complexity of the chosen artefacts represents one of the principal results to achieve. For this purpose, it is necessary to define clear operating methodologies both for raw data acquisition and processing. The main goal of this stage is to come to a real and complete 3D data acquisition. This result can be achieved using laser scanning and digital photogrammetric methodologies. Within these techniques the methodological approaches can be different. In the specific case, a long range laser has been used to realize a general 3D model of the artefact. The realization of high resolution textures mapping is an interesting field of this work. The problem can be tackled in two different ways: texturing the surface models obtained from the clouds of points or linking a corresponding RGB value to each acquired point. The quality of colour acquisition carried out by the 3D laser scanners is in most cases poor because the integrated sensors are characterized by a low geometric resolution. The implementation of suitable algorithms, in order to associate the colour to clouds points from the high resolution images, represents a good solution. In the last years the photogrammetric multi-imagine techniques have had a quick diffusion not only because they are more flexible then the classical stereoscopic techniques but above all for the possibility of realizing three-dimensional surface models from monoscopic images. This approach can be favourable for the realization of models of artefacts characterized by a simple geometry to integrate if possible by high resolution laser scanning techniques. The second stage is addressed to test

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advanced methodologies for management and communication of cultural heritage. The research work has been directed to define a standard model in querying the model through a multimodal guide. The main goal of this stage is to determine a procedure in processing 3D textured models so to make them become the base structure for interactive databases.

2.THE WOODEN CEILING IN THE SALA MAGNA

The Steri Palace in Palermo, residence of the Chiaramonte family, was built starting from 1320 on the eastern edge of Piazza Marina, near the city's ancient harbor. From 1605 to 1782, the Palace was the headquarters of the Inquisition Tribunal, a place of detention and torture. 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. The "Sala Magna" is a hall of rectangular shape (Figure 1), 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 1. The "Sala Magna"

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 2). 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.

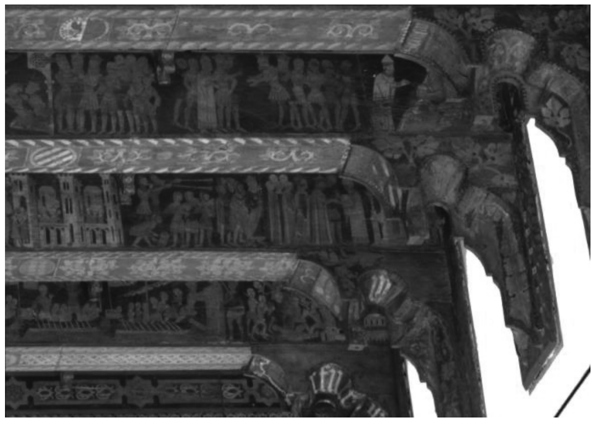

Figure 2. The consoles bearing the beams

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.
The ceiling has been made in 4 years from 1377 and 1380; it was painted by three local artists that were probably supported by books or by people having a good education in choosing the subjects of the scenes. Historians keep this ceiling as an important document of the middle age cultural references in Sicily: paintings are organized as short tales whose subject are taken from Greek mythology, the Old Testament, and medieval legends (Figure 3). The Chiaromonte family, who had started the construction of the Steri as their residence one century before, represented in this ceiling their cultural ambition as a counterpart of their political role.

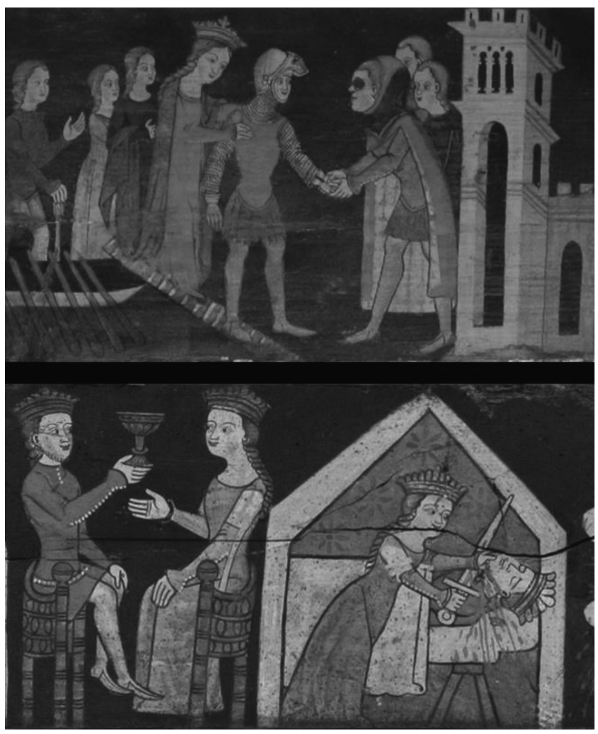

Figure 3. Scenes from the paintings. *Above*: Elena and Paride come to Troy. *Below*: Giuditta cuts off Salomone's head

The transformation of the Steri in residence of the Spanish governors, then in Court of the Holy Inquisition and last in public administration office has deeply altered the structure and the distribution of the original building, but has fortunately kept safe the wooden ceiling, hidden by false vaults. The restoration of the Steri, promoted by the university of Palermo that has established here its central administration, has given the ceiling its original aspect.

3. DATA COLLECTION

Metric data were collected with laser scanning devices[1]. Laser scans were used for the acquisition of a remarkable number of 3D 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. Laser data were collected first with a *Mensi GS200* scanner and in a second stage with a *Faro LS880* scanner (Figure 4).

Figure 4. Laser scanning survey. *Left*: Mensi GS 200 and reflecting targets on the wall. *Right*: Faro LS880

Point clouds collected with Faro laser device have covered, thanks to the wide field of view on the vertical plane, all the areas that could not be reached by the Mensi scanner e.g. the beams and the lacunars near to the walls of the Sala Magna.

Point clouds were oriented and referred using the correspondence between laser and topographical coordinates of targets[2]. Laser scanning survey of the ceiling produced a 15-million-point cloud.

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. In fact, considering the shape of the surfaces of the elements of the ceiling (almost flat), there was no need to use bundle adjustment techniques. A *Canon EOS mark II* digital camera, equipped with a full-format 16.1 megapixel CCD sensor and a 50 mm lens, and *Photometric* software by Geotop s.r.l. were used. In the first stage of photogrammetric survey zenith photos of the horizontal faces of the beams and of the lacunars were captured; vertical faces of the beams and consoles were shot with convergent photographs. Photos of the beams and of the lacunars were rectified using the coordinates of an adequate amount of the control points, referred to the mean plane of each element.

4. 3D MODELLING

The 3D model[3] of the hall was developed using laser scanning data; usually 3D surface models are extracted from the point cloud in an automatic way; the result are mesh surfaces whose resolution (density of triangles) is almost uniform. In this work the 3D model was produced in a different way: planar sections and surface interpolation were used to extract from the laser data the features needed in the modelling process (Figure 5).

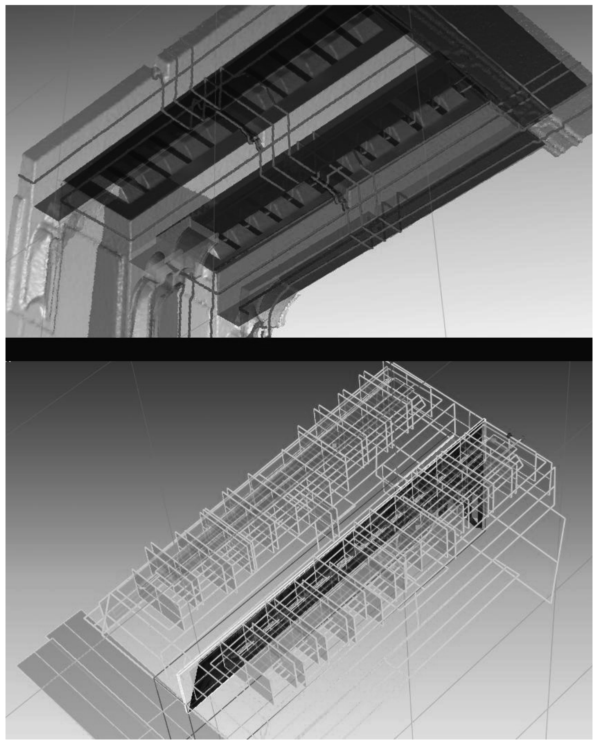

Figure 5. Features extraction from laser data

This way a certain “gap” between the real morphology and the 3D model was produced, but small gaps (deviations never exceed 7 mm) allow us to produce a flexible and handly model of the entire ceiling, with a resolution that is adequate to the local geometry of the surface. It takes to remind that the goal of this work is the production of a 3D interactive model as a support for the documentation of the paintings and as an help for people visiting the Steri. This process, directed to the use of the CAD models for visualization, rendering, or prototyping, requires a reconversion 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 (Figure 6).

[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).

[2] Laser data processing was performed with Inus Rapidform 2006 and Rapidform XOS.

[3] The 3D model carried out with the package Rhinoceros 4.0.

Figure 6. View of the 3D model

5. VISUALIZATION

In the ceiling covering the "Sala Magna" paintings are not less important than the elements defining structure and morphology. Therefore why the texturing process was cared not less than surveying and modelling. Rectified images were used for mapping beams and lacunars; convergent photos were used for false consoles.

The texturing process, which consists in assigning the raster image UVW coordinates that are linked to the XYZ coordinates of the model, was quite easy for the flat faces of beams, where just a dimensional and position adjustment was needed (Figure 7).

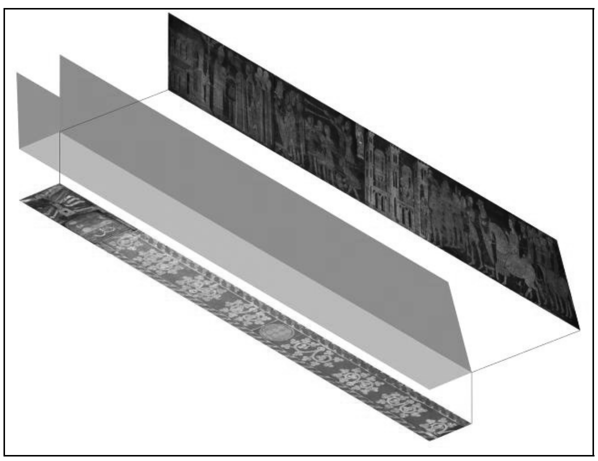

Figure 7. Texturing the faces of a beam

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 (Figure 8).

Figure 8. Texturing of a console

The 3-D model thus obtained allows the observation of paintings in their spatial context; 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.

The transformation of the model into a generic format for visualization (VRML) makes 3D exploration accessible also to users who do not have specific education or devices (Figure 9). The VRML model can also be accessed via internet, allowing users from distant countries to "visit" the Sala Magna.

VRML files can be edited in different ways and digital contents can be linked and accessed during the navigation; this way the model becomes something like a 3D homepage of a hypertext.

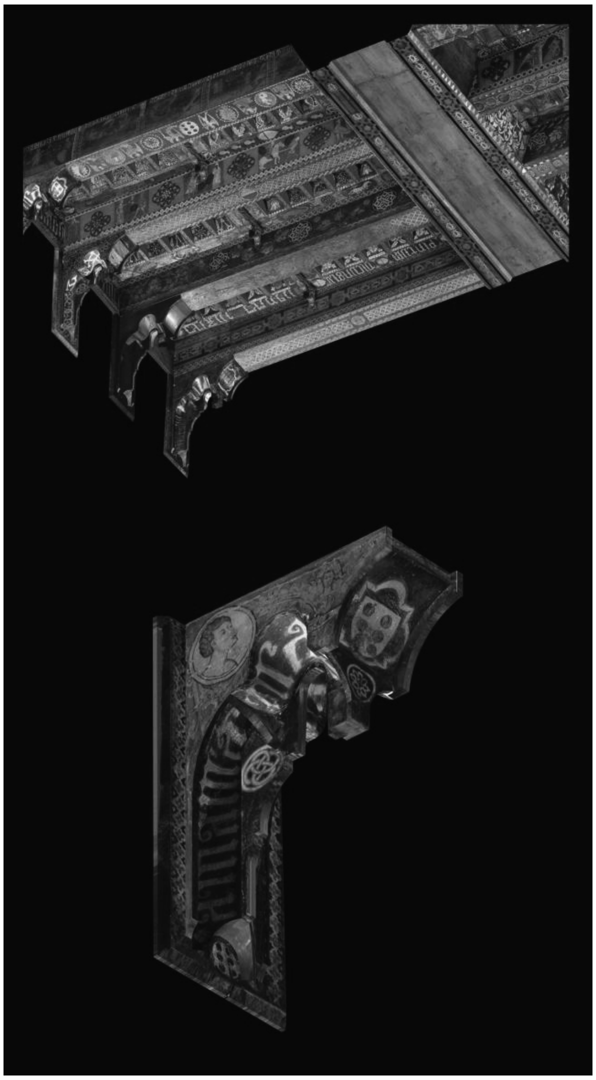

Figure 9. Views of the textured model

The user can freely navigate and inspect the model; if the cursor comes over a sensible area its form changes and a note informs that a link is accessible from that point. Multimedia files (raster images, html pages, music, videos, text) or further 3D models can be linked to the VRML file.
The model becomes an "open structure" whose extension is limited only by the imagination and the work of its creators. In the next future it is not hard to imagine a digital database linked to the 3D model, open to contributions from scientists from different countries.
VRML models can also be used to produce multimodal guides as effective support to people visiting the monument or for people accessing the Sala Magna via internet.
The research has received a meaningful contribution by teachers and researchers in computer science from the university of Palermo; the following section of this paper reports the results of a study addressed to the production of a multimodal guide for the wooden ceiling of the Steri.

6. THE MULTIMODAL GUIDE

The area of cultural heritage preservation and fruition has drawn an ever growing attention of artificial intelligence and human-computer interaction research in the last decades. This interest has led to the creation of clever and clever systems that can interact with the user in a variety of modes and in the most natural way.
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 proposed solution is based on a Multimodal Browser and aims at assisting users during the access to collateral information. 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.*

6.1 X3D and Voice integration

To address this issue one of the chances is the definition of open common standards for interface development. Nowadays integration of the hypertext HTML with VRML (Virtual Reality Modelling Language) has been already standardized providing a good approach in order to augment the efficiency and usability of 3D user interfaces. Starting from this point, in our work, we present integration of X3D (eXtensible 3D), an evolution of the VRML, with XHTML+Voice, an extension of HTML with the VoiceXML, an hypertext language for the voice interaction management.
As said before the interactive virtual environments has been implemented using the eXtensible 3D (X3D) technology. It is a new Open Standard developed by the Web 3D Consortium as evolution of the Virtual Reality Modelling Language, VRML.
In comparison with his predecessor VRML (that has been stopped to the version 2.0), X3D adds new nodes (e.g. the curved NURBSs and the Humanoid Animation).
The basic structure of the X3D environment at run-time is the scenes graph, in which all the objects of the system and their relationships are contained. The X3D run-time environment deals with different functionalities: visualizes the scene, receives input from different sources or sensories, coordinates the events process. Also it manages the current state of the scenes graph, the connections among the X3D browser and the external applications for the hyperlinking, the access through API, the cycle of life of the single objects, both built-in and defined by the consumer.
The X3D files were managed with the X3D-Edit development environment that provides developers with tools for the implementation of interactive 3D scenarios. The X3D standard supplies the possibility to set events inside the 3D worlds, through the use of script code.
In the X3D model of the application, some prearranged events are identified that allow to manage the interaction with the multimodal guide. This connection is managed through the javascript language.
Specifically, inside the 3D environment, some Grouping nodes, called anchors, were implemented each one able to contains different nodes. The Anchor grouping node retrieves the content of a URL when the user activates (e.g., clicks) some geometry contained within the Anchor node's children. If the URL points to a valid X3D file, that world replaces the world of which the Anchor node is a part, if non-X3D data is retrieved, the browser shall determine how to handle that data; typically, it will be passed to an appropriate non-X3D browser.

The implemented system overworks this second features of the anchor node. In our particular instance, the URL in the anchor node contains the code of an ad-hoc javascript function, that activates the vocal interface, as shown in Figure 10. This function loads an XHTML+Voice page that manage the vocal interaction with the user.

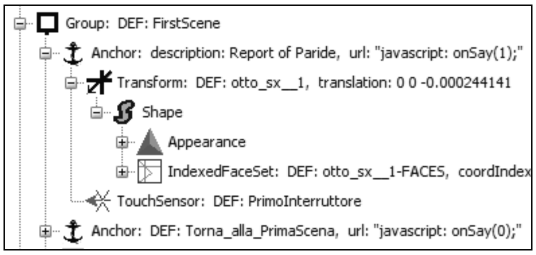

Figure 10. X3D-Edit environment screenshot,
Anchor node for the First Scene

The geometries, to which hyperlinks are "anchored" to, are well-defined areas of the implemented 3D environment, that were selected during the designing phase. For each area and ad-hoc Viewpoint node was introduced in the scenes graph, as shown in Figure 11.

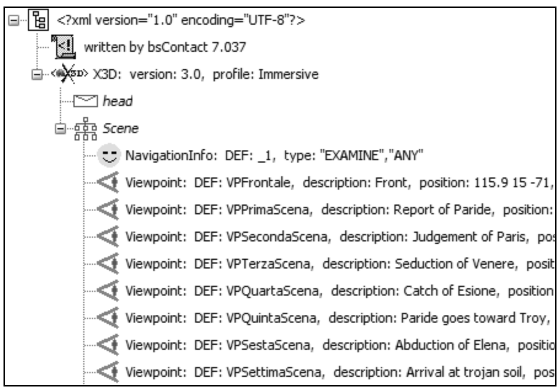

Figure 11. X3D-Edit environment screenshot, Viewpoint nodes

The Viewpoint node is considered as camera point of view that visualize a selected area in the world. When a Viewpoint is "active" the user see the world from this point of view.
The choice of the areas were made taking into consideration two aspects. The relevance of the area inside its context and the called forth interest of the scene for the user experience. The detected zones of interest in the virtual word are then tagged and highlighted with a tooltip that shortly describes the point of interest.
Once selected a point of interest, the vocal guide accomplishes the task to give information about the area to the user. A set of javascript functions manage voice guide activation coherently to the visual content of the page.
In Figure 12 is shown the integration between X+V and X3D technologies.
The interaction is performed with two different modality: visual input are used to navigate the virtual environment; vocal input are used to navigate meta content about the domain supplied by

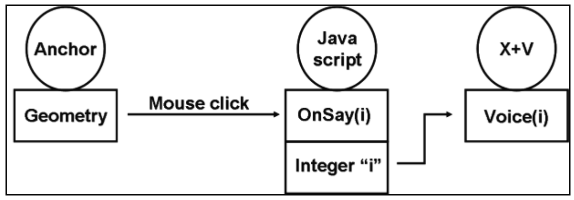

Figure 12. X3D and Voice integration

the virtual guide. During navigation the user can freely select the path of his tour, reminding that visual command take priority over vocal command.

6.2 The prototype

The implemented prototype aims at assisting a user during a visit in the virtual environment. 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.

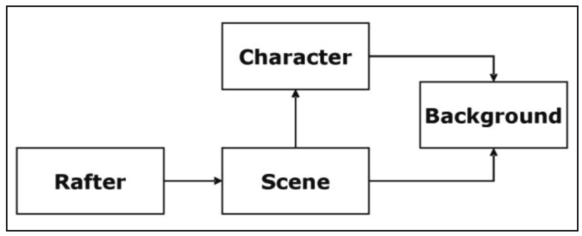

Figure 13. Formalization of context information

As shown in Figure 13, historical information about the paintings were divided in: scene description, character genealogy and background that is referred to a scene as prior events and/or to characters as flashback.
Interface features were decided by evaluating possible visit scenarios, assuming the virtual representation as a way to augment visitor experience on site.
The interaction is centred 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.
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 shown in Figure 14. 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.

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").

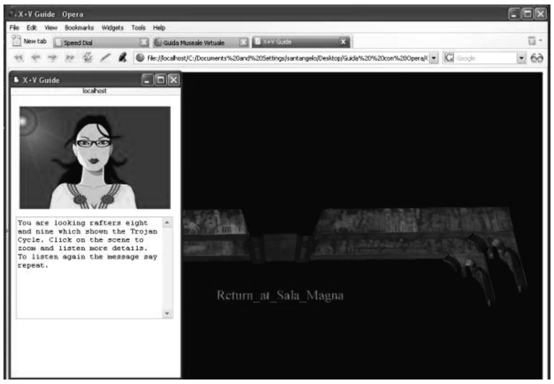

Figure 14. Dialogue and screenshot in the rafter perspective.

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 the sample dialogue in Figure 15, 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.
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.

Figure 15. Dialogue in the scene perspective

This approach provides user with a virtual guide that assist the virtual tour according to him/her preferences. Work is 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.

7. CONCLUSIONS

This paper proposed the aim of experimentation of innovative methodologies for the survey and fruition of Cultural Heritage.
With reference to the problems of the survey, particularly, integration among different types of laser-scanning instruments and between laser-scanning and photogrammetric techniques has been studied.
In regard to the aspect of the fruition, which today has become of greater importance with respect to the past, a system was tested directed to the visualization and navigation by WebGIS techniques of 3D rendered model previously produced, to allow a more widespread accessibility to the cultural heritage. With the use of this system 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. 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.

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