Proceedings of the 1st International EARSeL Workshop
CNR, Rome, September 30 – October 4, 2008

Advances on Remote Sensing for Archaeology and Cultural Heritage Management

Edited by
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Nicola Masini

CD–Rom included

ARACNE

Published for :
EARSeL – European Association of Remote Sensing Laboratories
CNR – IMAA (Istituto di Metodologie di Analisi Ambientale)
CNR – IBAM (Istituto per i Beni Archeologici e Monumentali)

Cover design: Nicola Afflitto (IMAA–CNR)

Published and distributed by Aracne Editrice s.r.l. via Raffaele Garofalo, 133 A–B, 00173 Rome, Italy.
T. +39 (0)693781065, www.catalogoaracneeditrice.eu

ISBN 978–88–548–2030–2

1st edition: September 2008

Development of integrated 3D methods for the creation of a DVR-based knowledge platform

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Keywords: Virtual Reality, Laser Scanning, Distance Visiting, Desktop Virtual Reality (DVR)

ABSTRACT

This study is one of the activities organised as part of the ByHeriNet project ("Byzantine Heritage Network: Rehabilitation, highlighting and management in the Eastern Mediterranean Basin"), promoted under the EU Programme known as INTERREG III B "ARCHIMED".

The main objective of the activities of the IbamITLab within the ByHeriNet project is the development of integrated methods for the creation of three-dimensional models using laser scanning techniques, digital photogrammetry, 3D photomodelling and direct surveying, applied to Byzantine sites in the province of Lecce and the region of Basilicata in the South of Italy.

The three-dimensional models established using these methods constitute an advanced information platform, able to represent the architectural morphology of the buildings under study with great accuracy at various scales, including both detailed elements and the monumental arrangement as a whole, as well as the textural features of the internal and external surfaces.

The main aim of this study is to enable the public to enjoy the results of archaeological and archaeometric research, via the web or stand-alone products, and to "virtually visit" the monuments using RealTime 3D visiting systems. The navigation platform allows the user to visualise complex scenes and DVR-based knowledge models in "full-screen mode" even on desktop computers. As well as showing the current state of the monuments, the visit includes reconstructions of previous phases in their history and virtual restorations of the Byzantine paintings. All the textures were obtained by processes of photomodelling and were applied to the geometrical forms in accordance with the radiosity algorithm, with lights and shadows of the 'area' type. The result is extremely life-like, almost indistinguishable from reality.

Figure 1: 3D restitution from laser scanning and Camera mapping of Madonna delle Croci church (Matera, Italy).

1. OBJECTIVES

The main objective of the Italian National Research Council's IbamITLab in the context of the By-HeriNet project is the development of integrated methods for the creation of three-dimensional models using laser scanning techniques, photogrammetry and 3D photomodelling, applied to Byzantine sites in the province of

Lecce and the region of Basilicata, with particular reference to those monuments with elements of special interest that are representative of the period in question.

The three-dimensional models developed using the integrated methods described below provide a use-ful knowledge base for representing architectural morphology on various scales with great accuracy. This includes both specific details and the overall monumental arrangement, as well as the textural characteristics of the interior and exterior surfaces.

Each monument was modelled and studied in relation to its environmental context, noting its underly-ing system of relationships, which is often the key to understanding the architectural strategies adopted. The main goal of this research however remains that of allowing the public to benefit from the results obtained, either via the web or stand-alone products, so that they may "visit" and enjoy the monuments using both 3D RealTime visiting systems and spherical and interactive 3D panoramas. Each three-dimensional model is thus integrated in a multimedia authoring system in which all the data formats available for the item in question (audio, video, VRML, QTVR, VR-Object, images, ta-bles, etc.) can be combined in a single environment. Descriptions of an academic and critical nature (historical overview, relations with other ancient contexts, exegetical analysis, etc.) are combined with technical and scientific methods of analysis and diagnosis (e.g. analysis of constituent materials, state of conservation, study of architectural characteristics, etc.).

In an interactive environment, it is possible to interact with the structures of the sites under study and search the associated Databases for drawings of the layout, topographical data, orthophotos and his-torical documents, together with information on the mineralogical and petrographic characteristics of the construction materials, plasters and paintings. The virtual visit is further enriched with CG (Com-puter Graphics) reconstructions that provide the user with a diachronic reading of the monument and enable him/her to better understand the transformations it has undergone.

The process of creating content relating to each monument studied may be summarised as follows:

1. Gathering of the historical documentation available;

2. Architectural survey of the structures, performed with methods appropriate to the distinctive charac-teristics of each monument;

3. Three-dimensional restitution and optimisation of the models in accordance with the predicted out-puts;

4. Extraction of the two-dimensional maps and video footage to be integrated in the computer vision systems or in the stand-alone publishing products (DVD Videos, VRML models, etc.)

5. Creation of virtual spherical panoramas (QTVR);

6. Implementation of the 3D models and QTVR contributions in VR knowledge platforms.

3. FIRST CASE STUDY: THE ABBEY OF S.M. DI CERRATE

The Abbey of Santa Maria di Cerrate, situated in open countryside in the municipality of Squinzano, a few kilometres North of Lecce, was founded at the beginning of the 12th century by Norman counts.

The aims of the architectural survey of the Abbey of Santa Maria di Cerrate are to document the current state of the building and construct the three-dimensional models necessary for the development of the knowledge platforms described above. Consequently, the survey operations concerned not only the individual surfaces of the church itself, but also the series of buildings that encircle the Abbey today in a "defensive wall" and form an inseparable part of the same monumental complex. Given this premise, the early phases the work focused on the acquisition of the basic photographic documentation and on the choice of appropriate techniques for the restitution of the monumental complex at a high level of detail and precision. As already mentioned, considering the aims of the communication products and the survey issues specific to this case, it was readily perceived that these requirements could be met by restitution techniques based on digital photogrammetry and photomodelling in particular.

The reasons for this choice obviously include their greater flexibility and ease of use compared to normal photogrammetric techniques, but above all the possibility they provide of obtaining three-dimensional models of great precision at very low cost (rif. Low cost met, CIPA). In this specific case, it should be stressed that the surveying difficulties resulting from the height of the buildings, together with the problems of accessibility to certain architectural elements (the rose, roofs, upper windows, etc.), mean that considerable effort (and additional costs) would have been required for the deployment of of the equipment necessary for a traditional photogrammetric survey. Given the conditions, the adoption of a system based on laser scanning was also excluded a priori, in that this would have required greater processing times in terms of post-editing and would have generated redundant data for the flat surfaces. In an architectural survey with specific aims such as this one, the key factor is the critical judgement of the surveyor, who must identify, by

means of a careful analysis of the architectural elements, only the essential points necessary for the restitution. This critical evaluation, which entails the recognition of corresponding points in different photographic shoots, is also the fundamental task in photomodelling surveys. In operational terms, it is sufficient to identify the vertices of each architectural element, or insert some targets on the surface being surveyed in the poorly characterised areas, in order to obtain three-dimensional models complete with textures mapped in UVW projection.

4. SECOND CASE STUDY, THE RUPESTRIAN CHURCH OF MADONNA DELLE CROCI

Entrance to the crypt is through a round arch with a simple rectangular door in the centre of a semicir-cular façade carved in the rock which contains a series of niches and engraved crosses. The interior, rectangular in shape and oriented East-West, is subdivided into two vaults separated by a segmental diaphragm arch. Each vault is supported at the sides by blind arches where, in the vault closest to the entrance, numerous crosses are engraved.

The survey of the internal walls of the crypt was performed with an time of flight laser scanner. The acquisition was based on domes of about six metres in radius, with a level of detail of the point clouds of 2-4 mm. Five scans were necessary, three inside and two outside, to describe the entire item with a good coverage of the undercuts.

The scanner proved to be fast and reliable, but the editing of the point clouds required a considerable effort on the part of the operator to resolve problems caused by exporting in the dxf format, which resulted in pronounced anomalies and discontinuities in horizontal bands at regular intervals. In each case the manipulation of the meshes using software dedicated to the management of point clouds resolved the problem satisfactorily, and the results are visible in the images shown in this article. The polygonal mesh was subsequently decimated in order to maintain the number of polygons within a limit that was empirically tested on normal consumer computers, in the order of 400-500 thousand polygons. In the texturing phase, this limit, imposed for reasons linked to the performance of the Realtime engine, considerably simplified the selection of the groups of faces to which each individual material was assigned. The internal walls were mapped using the Camera Mapping method, well-known and used in cinematography, but rarely used in other applications such as the restitution of monuments.

Our experience has shown the excellent performance of CM on curved surfaces, for example the apsidal wall or the underside of the arches of the lateral walls; on all the other surfaces an extensively subdivided planar projection was used, again to limit distortions in the undercuts as much as possible.

Figure 2: A screenshot of DVR platform with his navigation interface. Interiors of S. M. di Cerrate abbey.

Figure 3: 3D restitution from photomodelling approach of S. Maria di Cerrate abbey.

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