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Starting the CENOBIUM Project: The cloister of Monreale (Sicily) Revealed

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Abstract

The paper presents the guidelines of the CENOBIUM project and the first results on the capitals of the cloister of Monreale (Sicily). The CENOBIUM project aims at demonstrating the strength of the integration of modern representation and analysis technologies in the context of the knowledge, documentation and fruition of 3D cultural heritage. The wonderful capitals of the cloister of Monreale are the case study of our project. In fact, most of the capitals represent episodes of the Holy Bible and they can be completely appreciated, studied and documented merely by integrating 2D and 3D technologies. The paper describes the different acquisition and documentation modalities adopted in the project: high resolution digital imaging, short range 3D laser scanning for the capitals, long range 3D laser scanning for the cloister, panoramic views, integration of the geometry of the capitals with the high resolution color images. Moreover, it outlines the main components of the system which will allow the user to virtually move inside the cloister, to choose a particular capital, and to analyze and study the 2D, 3D and text information related to it. By means of innovative technological solutions, all the information, at the highest level of detail and resolution, will be available locally, on a kiosk installation, and on the web.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Methodology and Techniques, Digital Imaging, 3D Scanning

1. Introduction

The project CENOBIUM (Cultural Electronic Network Online: Binding up Interoperably Usable Multimedia) faces the necessity to improve scientific and educational communication on the one hand and public information systems on the other hand, integrating new investigation instruments, not systematically connected until now . It will provide a web-based, openly accessible work environment, which includes 3D models created by scanning, CAD-representations, digitized historical photographs and digital photography of the highest professional quality. The technical work will be devoted to the integration and extension of available technologies (database, image-viewers, 3D-viewers, content management, etc.) now dispersed and not-interoperative. The project points to the introduction of multimedia investigation of artworks as a regular research-instrument in the service of its different user groups. The specific case study considered for the assessment of our approach is a selected group of important capital-cycles in medieval cloisters of the Mediterranean region, starting with the cloister of Monreale. With the beginning of the 12th century a new type of sculpted capital evolved within the currents of Romanesque art which was to play a decisive role in changing and determining the future appearance of interior religious space and its cloisters.
The art-historical material is highly adequate for multi-dimensional representation, given the 3-dimensionality of the capitals and their spatial connection with the surrounding architecture - aspects that can not be explored adequately relying exclusively on 2-dimensional photography.

The cloister of the Cathedral of Monreale in Sicily demonstrates particularly well the diversity and the range of opportunities a Romanesque sculptor had in expressing his art. The monastic complex was commissioned by King William II and executed between 1174 and 1189. It unites various artistic currents of Romanesque monumental sculpture into an architecturally homogeneous setting. Each of the cloister galleries consists of 26 twin colonnettes, whereby the corner piers join the columns and capitals into groups of four. The southern and western galleries merge by creating a small square courtyard with a fountain in the center and five additional twin colonnettes with capitals. Researchers identified various contemporaneous workshops composed of artists from various Mediterranean countries, such as mainland Italy, France and Spain, who worked on the spoliated marble shafts and capitals. In this respect the high-quality execution of the cloister capitals of Monreale unites, with its rich formal and iconographic repertoire, the main currents of artistic production of the second half of the 12^{th} century.
In this paper we present the very first steps of this project, started on 2006. The initial work has been focused on the acquisition and processing of 3D and 2D data, i.e. the raw basic data that will be used to populate an interactive system which should integrate all the information in a easily accessible way. After a very brief overview of related work in Section 2, we describe our data acquisition experience in Section 3. The overall structure of the system which will integrate all the data is sketched in Section 4. Finally, we present our conclusions and the future work in Section 5.

Figure 1: *The Monreale cloister.*

2. Related work

Many previous works concern the use of 3D technology either to reconstruct digital 3D models of Cultural Heritage masterpieces or to present those models through digital media. An exhaustive description of those works goes well beyond the brief overview that we can draw in this section. We prefer to cite here only some seminal papers on the technologies proposed for 3D scanning and interactive visualization.
Automatic 3D reconstruction technologies have evolved significantly in the last decade. An overview of 3D scanning systems is presented in [CS00]. Unfortunately, most 3D scanning systems do not produce a final, complete 3D model but a large collection of raw data (*range maps*) which have to be post-processed. The post-processing pipeline is presented in the excellent overview paper by Bernardini and Rushmeier [BR02]. Many significant projects concerning 3D scanning and Cultural Heritage have been presented in the last few years [LPC*00, BRM*02, FGM*02, PGV*01, STH*03, BBC*04, BCF*04, BCC*05]. Some of these projects considered also the issues arising when the aim is to sample not just shape but also the reflectance properties of the surfaces [BRM*02, STH*03, LKG*03] and the mapping of this information on the geometry [CCS02, FDG*05].
The high resolution meshes produced with 3D scanning are in general very hard to render with interactive frame rates, due to their excessive complexity. This originated an intense research on simplification and multiresolution management of huge surface meshes [GH97, Hop99, CMRS03] and interactive visualization, where both mesh-based [CGG*04] and point-based solutions [BWK02] have been investigated.

3. Data acquisition and processing

The comprehensive acquisition campaign we performed in Monreale was the starting step for the creation of a large database of high quality 2D and 3D data. In the next subsections we describe the acquisition setup and the technology used for the different types of data. The specific high-quality devices used for the photographic campaign and the acquisition setup are presented in Subsection 3.1. Then, the technologies adopted to scan (with a triangulation laser scanner) a selection of the most important capitals of the cloister are presented in Subsection 3.2. The approach adopted for mapping the photographic detail on the capitals' 3D models and to obtain a very realistic digital visualization is described in Subsection 3.3. Finally, the entire cloister has also been digitized with a time-of-flight scanner and with panoramic imaging technology, as briefly described in Subsection 3.4.

3.1. High resolution digital imaging

A Sinar P3 digital camera was purchased by the Photo Library of the Kunsthistorisches Institut, providing for the integration of the digital backs Sinarback 54 H and Sinarback eMotion 22, both of them with a resolution of 22 million pixel (sensor resolution 5440×4080 pixel), as well as various Sinaron lenses. This is a very expensive but also very high quality device, which can produce impressive results if used by a professional photographer. The high-resolution digital images are created in a two-step process. First, a digital image is produced with a colour management tool by Gretagmacbeth, following the intent to save as much information as possible with the one-, four- or sixteen-shot

Figure 2: *An example of the set of photos acquired for sampling the color of each capital.*

(taken at different exposure levels). This master copy is used for producing further copies and for long-term preservation. Its size ranges from approximately 130 up to 520 Megabytes (TIFF format uncompressed, 16-bit colour depth and 300dpi). A working image copy is created from this master. This copy is digitally enhanced to allow improved quality on a low-dynamic range output device (screen or printing device). Its size is approximately 65 Megabytes (TIFF format uncompressed, 8-bit-per-channel colour depth, 4000×4000 pixels - approximately 33 cm on a 300 dpi printout). A set of 8 photos, documenting a capital, is shown in Figure 2.

Figure 3: *The acquisition setup adopted to scan the capitals.*

3.2. Scanning the capitals

High quality 3D models of the capitals have been produced by using a Konica Minolta VI 910 Laser Scanner (a device based on optical triangulation), which permits to acquire accurately geometry of an object with a sampling density of around 10 samples/sq.mm. and a sampling error lower than 0.05 mm. Since the scanner works at a distance between 50 and 100 cm from the objects, it was necessary to put it on a scaffolding, as shown in Figure 3.

It is well known that scanning any 3D object requires the acquisition of many shots of the artefact, taken from different viewpoints, to gather geometry information on all of its shape. Therefore, to perform a complete acquisition usually we have to sample many *range maps*; the number of range maps requested depends on the surface extent of the object and on its shape complexity. A number from 120 to 200 single scans (each scan samples around 0.3 Million points) was needed to cover the entire surface of each capital. In the first scanning campaign (February 2006), which lasted for an entire week on site, we were able to scan 20 out of the more than 100 capitals of the cloister. To sample this initial subset we shot nearly 4000 range maps. Each set of range maps has to be processed to convert it into a single, complete and non-redundant 3D representation. As usual, the processing phases are:

- range maps *alignment*;
- range maps *merging* (or fusion), to build a single, non redundant mesh out of the many, partially overlapping range maps;
- mesh *editing*, to improve (if possible) the quality of the reconstructed mesh;
- mesh *simplification* and conversion into a multiresolution representation;
- *color mapping* (see next Subsection).

In order to obtain detailed 3D models, we used the ISTI-CNR tools, which give the possibility to deal with large number of range maps and to produce the final model with the lowest possible human intervention. A complete overview of these tools is presented in [CCG*03].

Twenty highly detailed 3D models of the most artistically interesting capitals of the cloister have been reconstructed. The screenshots of two models are shown in Figure 4 and 5. The number of triangles of each model ranges from 4.1

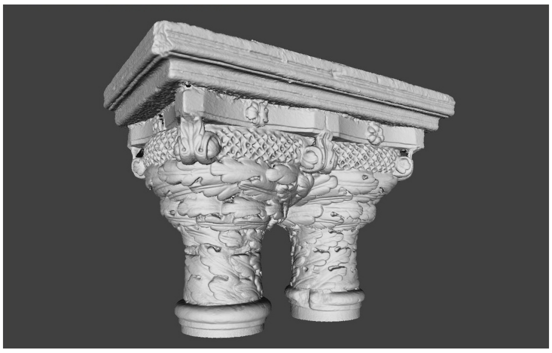

Figure 4: *The "Sh10" capital: ornamental leaves .*

Figure 5: *The "Sh20" capital: Samson.*

to 6 millions, depending on the shape complexity and size of each capital. We show in Figure 6 that even when a limited degree of mesh simplification has been performed, the detail of the geometry are preserved and the capitals can be represented in a very realistic way.

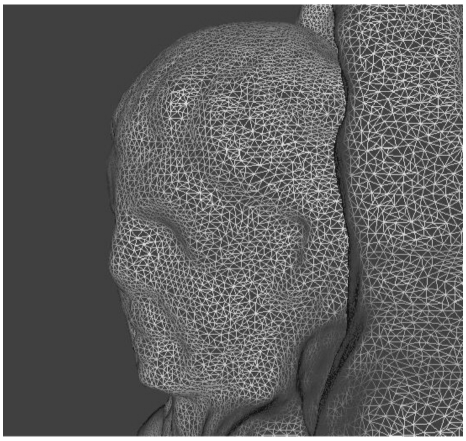

Figure 6: *A wireframe rendering of a small section of the "Sh23" capital (section height 5 cm.).*

3.3. Integrating color on 3D geometry

As already mentioned in the previous subsection, color mapping is an important step in the scanning pipeline. As a result of our acquisition campaign in Monreale we had high quality 2D and 3D information: the objective was to integrate them in a unique model, preserving the detail of both color and geometry.
In order to produced a detailed colored model starting from the set of photos provide, two phases are necessary:

- each photo has to be "aligned" to the model: the extrinsic (position in the space) and intrinsic (focal length and lens distortion) parameters of the camera which took the photo have been estimated with an appropriate tool [FDG*05];
- due to the highly detailed geometry, we chose to represent color following a per-vertex approach: for each vertex, the color assigned is computed as a weighted sum of the contributions of every photo which framed that vertex.

Figure 7: *The model of "Sh37" capital with color information.*

Following this approach, we produced a set of very detailed colored models: an example is shown in Figure 7. The union of 2D and 3D information can lead to a new way to archive and remotely represent Cultural Heritage objects.

3.4. Digitizing the cloister in 3D and as a panoramic image

The complete cloister has been also the focus of other digital acquisition actions. We planned to produce a 3D model of the entire cloister together with high-resolution panoramic images. The goal of these acquisition is first for the sake of providing a digital documentation and improved knowledge, but also to have digital models which could be used as a visual index to access the single capitals.
The panoramic images have been created by processing a set of digital photos (medium resolution, acquired with a consumer digital reflex camera) with the Stitcher tool by RealViz inc.
The 3D model of the entire cloister has been produced with

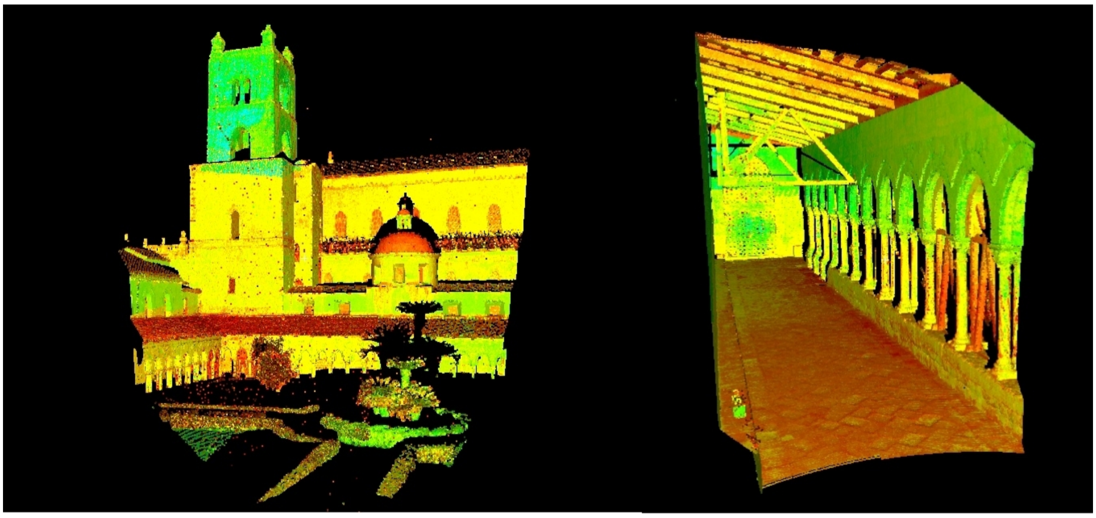

Figure 8: *Examples of time-of-flight scannings.*

a Leica Geosystems HDS 2500 time-of-flight scanner. Time-of-flight devices give the possibility to scan large areas in a short time, with an error in acquisition of less than 1 cm. We show an example of the results of several scans depicting a portion of the cloister in Figure 8.

4. Exploring the capitals of the cloister of Monreale

Figure 9: *Visualization of a capital using Virtual Inspector.*

With the first phase of the CENOBIUM project we have just scratched the work we planned. Just 20% of the capitals have been acquired (even though they are the most significant, from an artistic point of view).
The main goal of the project is to make these data available to both experts and public. This will be implemented by using the ISTI-CNR VIRTUAL INSPECTOR tool (see Figure 9). VIRTUAL INSPECTOR provides a framework which allows the easy inspection and virtual manipulation of a complex and highly detailed 3D model. The system allows also to add to the 3D surface a number of *hot spots* which could be used to link multimedia information to selected points of the surface (see the small red circles with an inscribed *i* in Figure 9); by instantiating hot spots we can tell the story of the artifact or encode annotations on the mesh. The system inter-operates with a standard web browser, which supports the visualization of the MM content spatially indexed by the 3D mesh. *Virtual Inspector* has been recently extended to work also on the net, by adopting a remote rendering approach, and has been already used for a number of projects (e.g. [BBC*04, BCF*04]).
The final goal of the CENOBIUM project is also to contribute to the evolution of the VIRTUAL INSPECTOR system, since we plan to transform it from a static system (i.e. all the links should be defined statically) into a dynamic and cooperative system, where users will be allowed to add hot spots and the corresponding MM descriptions via an easy to use interface, following the "Wiki approach". The details of this will be the subject of our future work.

5. Conclusions and future work

We have presented the overall goals of the CENOBIUM project and the results produced in the first phase of the project, devoted to the acquisition of the digital models (2D and 3D) of the selected case study: the cloister of Monreale. Therefore, the work so far has been mostly technical: acquiring 2D/3D data and setting up the HTML and interactive framework needed to show them both locally (a kiosk installed in the Kunsthistorisches Institut) and on internet: the focus of the second phase, i.e. our future work, will focus on some extension of the Virtual Inspector tool, to make it a cooperative instrument, and the production of all the multimedia content needed to enrich the visual digital representations of the sculptures of the cloister.

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