CENOBIUM – Putting together the Romanesque Cloister Capitals of the Mediterranean Region.

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Abstract

CENOBIUM (Cultural Electronic Network Online: Binding up Interoperable Usable Multimedia) is a Cultural Heritage project regarding Romanesque cloister capitals from the Mediterranean region. The central aim of this project is to illustrate cultural exchange in the twelfth and thirteenth centuries through the example of architectural decoration. In this ambit, three Cloisters have been considered until now; the cloister of Monreale (Sicily), the cloister of Sant'Orso in Aosta and the cloister of Cefalù (Sicily). For the most important capitals of these cloisters several high resolution digital images and highly detailed coloured 3D models have been produced.

This big amount of data has been integrated in a web application where, textual descriptions, high resolution images and 3D models can be accessed from the same page for each capital. Moreover, a simple mechanism permits to compare images and models of capitals of any cloister: the user can select them during the exploration, and then a simple tool (called LightTable) can download and visualize them on the computer. In this way, it is possible to compare the selected elements, so that further similarities between them can be found and easily investigated.

In conclusion, the CENOBIUM website is a successful integration example of different types of data, in the context of an environment which is devoted not only to the wide public, but also to the community of experts and scholars of the Romanesque art.

Keywords: Romanesque art, 3D scanning, integrated information, website, multimedia, Cultural Heritage.

Introduction

The use of new technologies in the context of Cultural Heritage has been an important issue since the 19th Century. The advent of new means to acquire and visualize information has brought to several revolutionary changes in the way Art and History are analyzed and presented.

More recently, 3D Scanning and digital photography provided ways to easily collect accurate information about the geometry and the appearance of objects of interest. The integration of these data with the other "usual" ways (like drawing or texts) to describe an artefact is still an open issue.

In particular, the aim is to go beyond the mere archival and visualization of all the data: it is indeed critic for the experts and the restorers to be able to access and manipulate all the information in order to enhance the quality of work, both in terms of speed and of data analysis.

The CENOBIUM project aims at demonstrating the potential benefits of the integration of modern techniques of representation with cutting-edge web technology in the pursuit of new knowledge about artefacts of the past. The central theme of this project is the articulation of the dynamics of cultural exchange at work the twelfth and thirteenth centuries through the medium of architectural decoration. The specific case studies currently being considered for the assessment of our approach are a selected group of capital cycles, found in medieval cloisters throughout the Mediterranean.

CENOBIUM provides a web-based open-access research environment, which includes 3D models created by combining high-resolution scanning with on-site digital photographic campaigns of the highest professional quality. The technical tools dedicated to the integration and extension of available technologies include databases, image-viewers, 3D-viewers, content management, and the innovative *LightTable* tool (described in the next), as well as other digital tools and media.

Cenobium offers the user the opportunity to fully manipulate the 3D images of the capitals in order to allow for maximum visual clarity from any point of view, including high-resolution zoom capability. This allows convenient and interactive access to the formal, narrative, and material contents of the capitals that can exceed even on-site study of the cloister. Cenobium will provide for more comprehensive appreciation, documentation, and interpretation of the site by allowing the user to virtually move inside the cloister itself, to focus in on a particular capital, and to analyze and compare capitals from different cloisters at the same time on the same screen. By means of innovative technological solutions, all data (at the highest level of detail and resolution) will be accessible at a dedicated kiosk installation in the institute, locally on private computers, and from anywhere on the World Wide Web. One of the main components of this innovative solution is the *LightTable* tool. This works as a shopping cart in an e-commerce website; the users select items during the navigation in the website, but they can compare them instead of buying such items. Specifically, the high-res photos and the geometry of the capitals can be selected.

In this paper we will describe the steps which brought to the creation of the prototype of this integrated environment, which was made available online at the address http://cenobium.isti.cnr.it/ . First, we will present the motivations which led to choice of the Romanesque cloisters around Europe as a large and promising test case. Then, we will shortly describe the technologies used to acquire and process the data which are present inside the collaborative environment. In particular, the pipeline and the tools used to produce the accurate coloured 3D models of the capitals will be presented. The Section about the website will show how all the data were integrated in the context of the developed web application, with particular attention to the mechanism which helps the user in comparing the data from different cloisters around Italy. Finally, the discussion and the conclusions will underline the achieved results and the future work.

The Romanesque cloisters around Europe: a complex and promising test case

The cloister of the Cathedral of Monreale in Sicily was the starting point of the Cenobium project. Its high quality Romanesque sculptural programme is extremely well suited to the technological analysis. Executed between 1174 and 1189 under the patronage of King William II, this cloister unites various artistic currents of Romanesque sculpture then circulating in the Mediterranean into an architecturally homogeneous ensemble. Along with Monreale, the cloisters of Sant'Orso in Aosta (c. 1150) and Cefalù (c. 1131/1166 o 1185/1189), belong to the few cloisters in Italy that display an extensive capital programme comprising both narrative and figural representations. The cloister in Aosta, for example, stands as an exemplary monument of the artistic development of medieval capital design in the Mediterranean and, stylistically, constitutes a bridgehead between the French and Italian cloister type.

The Italian Medieval cloisters (Monreale, Cefalú, and Aosta, shown in Figure 1) are only some of the examples of the Romanesque art, which includes several contemporary Spanish and French examples.

Shortly before the turn of the twelfth century a type of capital emerged in Romanesque sculpture that profoundly influenced the overall character of sacred spaces and monastic cloisters and became a primary element of medieval sculptural decoration of architecture. Previously, capital decoration had confined itself mainly to ornamental, vegetative, zoomorphic, or anthropomorphic forms. Now, however, it broadened its spectrum to include narrative cycles, thus taking on the added function of depicting stories from the Old and New Testaments, historical events, *exempla*, satirical scenes, and allegories. These cycles of historiated capitals integrate narrative elements into their particular

physical contexts. The nature of this type of cloister design – with free-standing columns and a moving viewer - is particularly well suited to narratives that must be scene from all sides.

Therefore, they afford the possibility of telling stories through a series of relief compositions, while facilitating a dialogue among and between capitals and other decorative elements of the cloister. Of additional importance is the spatial interrelation between the capital and the functional design of the cloister complex. The arrangement of themes and motifs on the capitals permits, in some cases, an aesthetic and physical interaction on the part of the viewer and gives us an idea about the liturgical role and ritual practices associated with the cloister.

Moreover, the similarities between capitals around Europe can bring to the discovering of points of contact between different sculpting schools, which can be consequence of a common way of thinking or of contacts and contaminations between the artists.

Data collection and processing

The comprehensive acquisition campaigns performed in Monreale, Aosta and Cefalù brought to the creation of a large database of high quality 2D and 3D data. High-end devices were used for both image and geometry, as shown in the next subsections. Then the data were performed using various non-commercial tools, in order to produce extremely accurate colored 3D models.

High resolution digital imaging

A Sinar P3 camera was purchased by the Photo Library of the Kunsthistorisches Institut, providing for the integration of the digital multi-shot-mode Sinarback 54 H with a resolution of 22 million pixels (sensor resolution 5440×4080 pixels), 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 color management tool by Gretagmacbeth, following the intent to save as much information as possible with the one-, four- or sixteen-shot (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): an example is shown in Figure 2, left.

The photographic campaigns on the cloisters were performed by acquiring 8 images for the highly interesting capitals and 4 or less images for the low interest capitals. This brought to the acquisition of a total of 690 images for the Monreale cloister, 270 images for the Aosta cloister and 180 images for the Cefalù cloister.

Geometry acquisition: scanning the capitals

For two of the acquisition campaigns (Monreale and Cefalù), a Konica Minolta VI 910 Laser Scanner (a device based on optical triangulation) was used. Triangulation scanning 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 scaffolding. 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 several range maps were needed; 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 of the surface) was needed to cover the entire surface of each Monreale capital. In the case of Cefalù capitals, due to their smaller size and more simple geometry, a number from 50 to 80 was necessary. The Monreale scanning campaign (February 2006) brought to the acquisition of 20 out of the more than 100 capitals of the cloister (Baracchini *et al*, 2006), with a total of nearly 4000 range maps. The Cefalù scanning campaign produced ten 3D models, with a total of nearly 800 range maps.

The acquisition of the geometry of the Aosta cloister capitals was performed by ITABC-CNR of Rome using a Menci ZScan, which employs images taken from calibrated images to produce accurate range maps. This technology heavily relies on Computer Vision techniques for 3D reconstruction from images. The main difference with the Minolta device is the final accuracy of the geometry that is slightly lower. Moreover, the numbers of samples are hundreds of thousands instead of millions. Using this technology, eighteen 3D models were produced, starting from 24 range maps for each capital.

The range maps from both Minolta and Menci ZScan devices were processed to convert it into a single, complete and non-redundant 3D representation. The processing steps followed the usual 3D scanning pipeline (Bernardini and Rushmeier, 2002):

- 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).

This processing steps was obtained through 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 (Callieri *et al*., 2003).

The number of triangles of each model ranges from 4 to 6 millions, depending on the shape complexity and size of each capital.

Adding color to the 3D geometry

As already mentioned in the previous subsection, color mapping is an important step in the scanning pipeline. As a result of the acquisition campaigns 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 produce a detailed colored model starting from the set of photos provided, 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 were estimated with an appropriate tool (Franken *et al*., 2005);
- 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 (Callieri *et al*., 2008a).

Following this approach, we produced a set of high detailed colored models (a snapshot of a model from the Aosta Cloister is shown in Figure 2, right). The union of 2D and 3D information can lead to a new way to archive and remotely represent Cultural Heritage objects.

In the next Section, which describes the CENOBIUM website, we describe how this data are integrated in the web application.

The CENOBIUM website

Nowadays, several digital instruments to archive and analyze the data about artefacts of interest in the ambit of Cultural Heritage are available. As previously stated, one of the main problem is the integration of all of such data in a useful manner. Obviously, the integrated information system can be designed for specific purposes, following the requirements of certain kind of users (e.g. hobbyists, tourists, experts or researchers).

Previous approaches in the presentation of multimodal data (Balzani *et al.*, 2004; Baracchini *et al*, 2004) were mainly devoted to the integration of 3D models with textual information. These environments were created to provide an easily navigable environment for naïve users.

The Cenobium web application tries to be an integrated environment for several categories of users. For example, naive users can simply read information about the capitals, analyse the high-resolution images and navigate the 3D models (Callieri *et al.*, 2008b). At the same time, experts and academic researchers can exploit all the potential of this environment in order to make further studies about the capitals.

The current web application includes two Cloisters (Monreale and Aosta) and a third one (Cefalù) will be soon available. For each Cloister, a brief description is provided. The most interesting section is the one about Capitals. In this section, the users can explore in an integrated manner all the multi-media information related to each capital. After a capital of the Cloister is chosen, all the information is shown in a single web page (see Figure 3). In order to be able to choose the capital of interest, in the upper part of the page a stylized version of the Cloister is shown; the capitals are arranged as in the real cloister, and their position is highlighted. The left part permits to navigate through all the images coming out from the photographic campaign: in particular the user can choose the side of the capital to visualize. By clicking on the selected view of the capital the full-resolution image can be visualized. Since the resolution of such images is very high, a dedicated image server, called *Digilib*, gives the possibility to navigate them interactively. A textual description containing historical information is given in the right part. If available, the description can be expanded to shown a more detailed one. The availability of a 3D model representing the chosen capital is shown in the bottom part.

Both the 3D model and the images can be selected as items into the LightTable tool, by clicking the appropriate option. It is important to underline that in order to enable such advanced functionalities the LightTable tool required to be previously installed on the PC where the website is explored. The tool can be downloaded for the installation directly from the website. When an item is selected, the LightTable takes care to download the item (high-resolution photos or 3D geometry) on the local PC (see Figure 4, left). Then, for whose items that are ready-to-use, the user has the possibility to visualize them simultaneously for comparison. In this way, further similarities between the items can be found and investigated easily (see Figure 4, right). The maximum number of items that can be visually compared is four. Even if the development of this tool is still in progress the LightTable could become a very useful resource for the work of art historians.

Preliminary presentation of the web application during the Annual meeting of the German Art Historians (25th – 29th March 2009 at Marburg) and as a part of the exhibition *Sicily. From Ulysses to Garibaldi* in the Art and Exhibition Hall of the Federal Republic of Germany (25th January – 25th May 2008 at Bonn) has shown that the objectives of the project are fulfilled. Both interested people and academic experts have found this way of present and access multimedia data about the capitals useful and with high potential to conducted in-depth studies.

Discussion and conclusions

As a comprehensive and long-term project, Cenobium not only serves as an instrument for academic research, but it also provides for the interests of several other branches of Art History.

For example, a possible starting point for research into the lively artistic exchanges of the 12th and 13th centuries, which precludes a monographic analysis, is the question concerning the relative coherence between programmes and capital cycles and the analysis of their specific design characteristics.

The Italian Medieval Cloisters (Monreale, Cefalú, and Aosta) form the first part of the project, which will expand to include contemporary Spanish and French cloisters. Cloisters that are no longer extant or that have undergone extensive rebuilding can now be usefully compared with capitals preserved in museums, while under certain circumstances destroyed structures can be reconstructed.

CENOBIUM combines both traditional and innovative methods of Art History with the latest technology in order to open up new horizons of art historical scholarship that have not, until now, been exploited to their full potential.

One of the main future developments of the Cenobium website will be the inclusion of other Cloisters and the development of a component to make it a collaborative environment where new contributions can be added and discussed in a "Wiki fashion".

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Figures (All the figures are two columns 170mm wide)

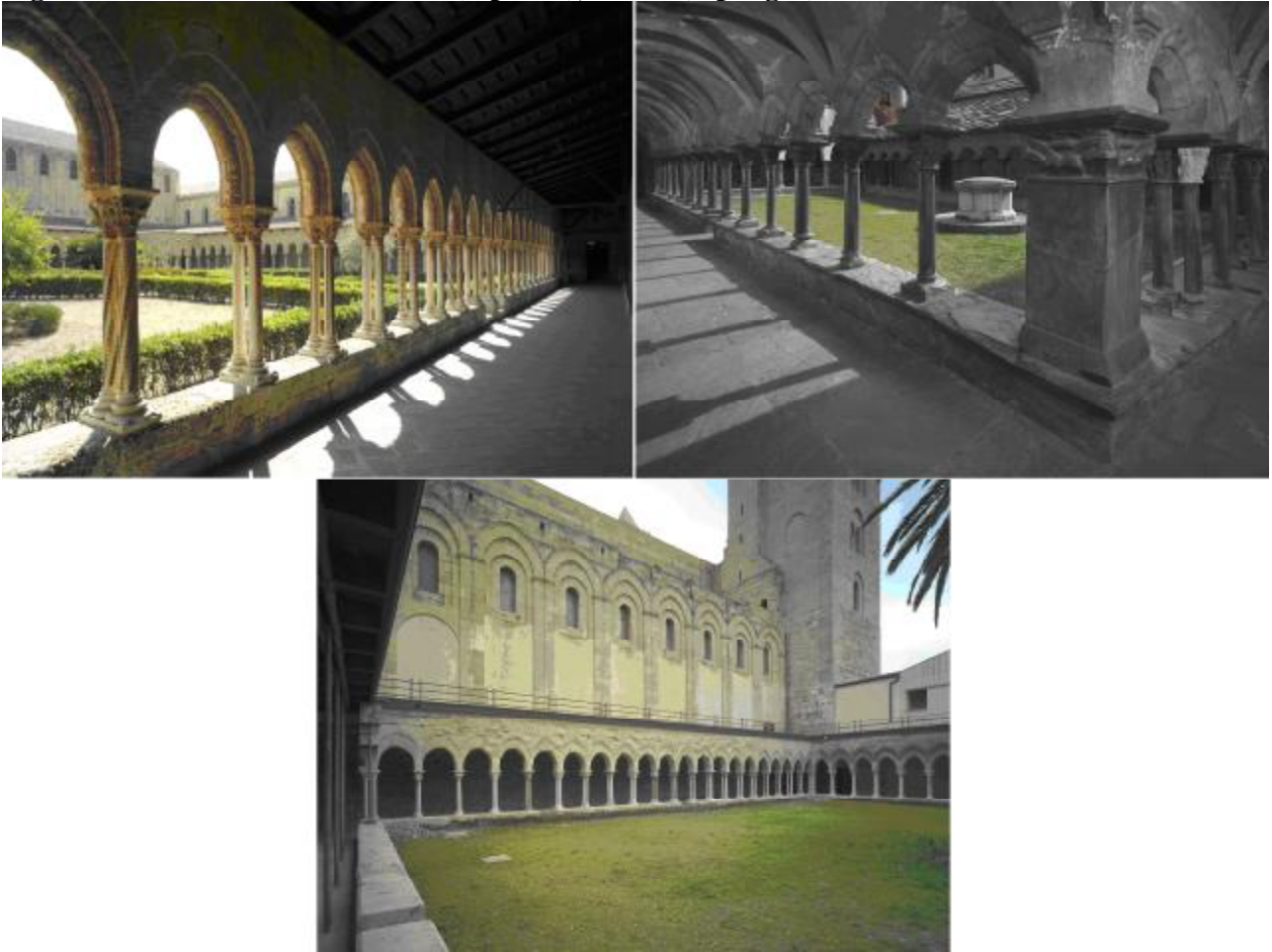**Figure 1. A view of the Monreale (top left), Aosta (top right) and Cefalù (bottom) Cloisters**

Figure 2. An example of an acquired image of a capital from Monreale (left) and a snapshot of a colored 3D codel of the Cloister of Aosta (right)

Figure 3. Integrated information for the N14Sh13 capital of the Monreale Cloister

Figure 4. The lighttable: the list of the items selected by the user (left) and an example of visual comparison of four elements (right)