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CENOBIUM 10 YEARS AFTER: AN EVOLVING PLATFORM FOR DIGITAL HUMANITIES

1. Introduction

1.1 *Photography and art history*

More than any other of the Humanities, art history is an image-based academic discipline. Before 1839 – the year when various experiments in photographic processes were published – those interested in the fine arts had just their own memory, sketches or reproduction prints at their disposal. Only photography with its visual memory made possible the method of comparative visual analysis of artworks or works of architecture in different locations which is so fundamental to art history (Bader, Gaier, Wolf 2010). Although the debate on the objectivity, evidence, indexicality, and materiality of (also digital) photographs requires a discourse of its own, we can say that art history established itself as a discipline in its own right only by dint of photography and associated projection techniques. Likewise, one can speak of an art historical perspective, which is informed by photography and tied to reproduction technologies (Edwards, Hart 2004; Caraffa 2009; Daston, Galison 2010; Edwards 2014).

1.1.1 From the image projector (“Bildwerfer”) to 3D simulation

In the nineteenth century – following the camera obscura, the magic lantern and the peep show (zograscope) – stereoscopy became very popular not just with art-loving travellers, as various photographic processes and reproduction technologies were developed (Manodori 2016). Stereoscopy is based on the principle that two images (e.g. photographs, engravings, drawings) capture a subject with a deviation of approx. 6-7 cm and, when viewed through separate lenses, create the impression of three-dimensionality in the human brain (Hick 1999; Gronemeyer 2015). In doing so, stereoscopy conveys three-dimensional depth, albeit without reproducing the various perspectives of an object. Moreover, this technical simulation of spatial perception is – unlike the magic lantern or the skioptikon – tied to individual use and as such subject to the viewer’s subjective sensory impression (Stiegler 2006, 57-85). Stereoscopy was mostly superseded only with the introduction of film which, though not (yet) offering the spatial depth effect of stereoscopy, at least made it possible to visually circle an object or convey a representation of movement in space. Ever since the 1830s, the scientific use of photographs of photo series was always emphasized (Kemp, Amelunxen 1980-2000; Siegel 2014).

Harnessing technological progress, art history also adopted, aside from photography, the use of physical-technical instruments. Without damaging the object, X-ray machines and CT scanners can reveal what lies underneath a surface, such as underpaintings or the armature of a plaster figure, and thereby visualize a creative process in the form of "pentimenti", preparatory sketches or different versions and states of an artwork. Traditional analogue and electronic imaging techniques as well as their cataloguing were expanded to include digital work tools into a Virtual Research Environment. These allowed for the creation of structural models based on plans for unbuilt or hypothetical architecture, for unrealized monuments and art objects, arrangements of historical, no longer extant complexes, temporary installations such as exhibitions – with possible applications ranging from the visualization of the hidden to the creation of mock objects.

Of course, these technologies as well as computer simulations, computer-generated imagery and virtual photography in general are not primarily developed for cultural heritage purposes. Nevertheless, their applications as non-invasive techniques are indispensable in this field – not least to make the visualization of an artwork or architecture available in multiple places at the same time, adjustable in size and colour and independent of the time and space of their original locations.

1.2 *The specific research and study domain of the CENOBIUM project*

Such a vision is the starting point of the web-based, publicly accessible project CENOBIUM which was developed by the Kunsthistorisches Institut in Florenz, Max-Planck-Institute (KHI-MPI) by Ute Dercks, and Gerhard Wolf and the Istituto di Scienza e Tecnologie dell'Informazione "Alessandro Faedo" (ISTI-CNR), by Federico Ponchio, Massimiliano Corsini, Marco Callieri, Matteo Dellepiane, Claudio Montani, and Roberto Scopigno, together with various international cooperation partners.

The central aim of this project is to illustrate and analyse the complex interconnections of cultural and artistic exchange in the twelfth and thirteenth centuries through the example of architectural sculpture (Fig. 1). The focus is on cloisters with series of especially historiated capitals, that is, on column and pilaster capitals with reliefs depicting stories. These usually biblical, hagiographic or allegorical narratives wrap in several scenes around the capital, so that the stories can only be comprehended in the sequence, meaning by physically moving around the column.

Three of the most important centres of Romanesque cloisters are located in the Languedoc-Roussillon region in France, in Northern Spain and in Sicily. Architects and sculptors who were active superregional usually realized the complex and ambitious decorative concepts. They reflect the art of the time which, as a result of increasing mobility, was disseminated via pilgrimage and

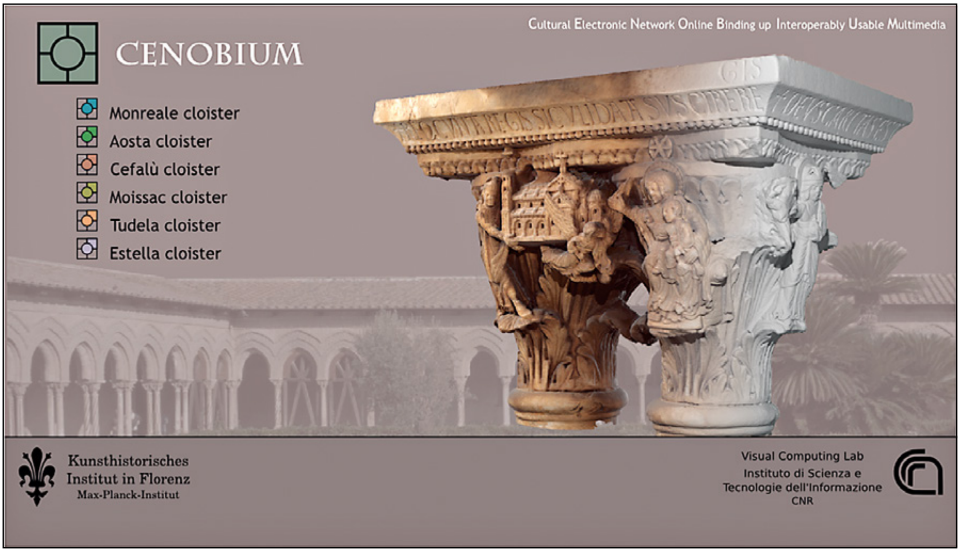


Fig. 1 – The homepage of the CENOBIUM project.

trade routes within Europe as well as between the metropolises and monasteries in the Mediterranean region.

1.2.1 The historiated capital

Shortly before the turn of the twelfth century, a type of capital emerged in Romanesque sculpture which 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. As an integral architectural component, the Romanesque capital incorporated this new narrative element into its particular physical character. Its three-dimensional aspect lent itself particularly to cloisters, where free-standing columns could be viewed from all sides. Thus, they provided 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 (Dercks 2006).

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 functional interaction on the part of the viewer and gives an idea about the liturgical role and ritual practices associated with the cloister.

1.3 *Goals and polices endorsed*

Through modern technologies such as high-resolution digital photography, 3D digitization as well as an interactive web application it is possible to overcome barriers such as distance from the object, unfavourable light conditions, architecture-related obstacles or preventive conservation measures obstructing on-site examination of the capitals. They allow to study the architectural sculpture in its surface structure, colour, material texture and relief work in the way the sculptors envisioned and at the same time in the way they relate to the architectural context. Going beyond art historical questions, the CENOBIUM project is also a useful tool for the conservation and restoration of the capitals, which are exposed to all environmental influences at the open cloister. Because the photographs not only make material details visible, but the 3D models also create a virtual form by means of active or passive surface-scanning, which could be compared to 3D reconstructions made in the future, e.g. to evaluate potential conservation issues.

In the past ten years, a total of six cloisters in Italy, France and Spain have been made accessible for the project and recorded in more than 2000 digital photographs by the photographer Roberto Sigismondi on behalf of the KHI-MPI (Photo campaigns: 2006 in Monreale; 2008 in Aosta; 2009 in Cefalù; 2014 in Moissac; 2015 in Tudela and Estella). Assistance and post-processing: Andrea Marinello (2006-2015), Dagmar Keultjes (2006-2008), Silvia Campanella (2009), Nathalie Voß (2014), Barbara Gallas (2015), Cristian Ceccanti (2014-2015), Stefano Fancelli (2014-2015). The 3D models in Monreale and Cefalù were made by ISTI-CNR with a Konica-Minolta scanner (3D scanning and post-processing in Monreale: Marco Callieri, Massimiliano Corsini, Matteo Dellepiane, Valentino Fiorin, Guido Ranzuglia, Marco di Benedetto, Andrea Spinelli; in Cefalù: Marco Callieri, Massimiliano Corsini, Matteo Dellepiane). In Aosta, on the other hand, the 3D scans were made as part of a project of the Institute for Technologies Applied to Cultural Heritage (ITABC) of the National Research Council, Rome, Italy in cooperation with the Superintendence for Cultural and Environmental Heritage of the Valle d'Aosta and were subsequently integrated into the CENOBIUM project (Salonia *et al.* 2009). This productive cooperation with ITABC-CNR should become a business model for CENOBIUM or other similar projects.

In the past ten years, the digital 2D or 3D recording of many cloister capitals has been financed with public project funds from regional or State governments or by grants at the European level. Yet it is still very difficult to convince those responsible for these projects to make their usually high-quality photographs or 3D scans available for the CENOBIUM platform and thereby make their products also accessible to the public and become a partner in the project. The obvious fear of misuse or loss of control over data or rights of use as well as some internal organizational problems, including issues of responsibility, are not always plausible. Moreover, they prevent an extended publication and access to the expensively produced digital photographs or scans (usually with public money). The excellent cooperation with ITABC-CNR and the Superintendence of the Valle d'Aosta has so far been a laudable exception and it was beneficial for both sides.

From the very beginning, CENOBIUM was conceived at an international level as a multilingual, interactive work-in-progress project, which should be freely accessible on the Internet. The project's website (http://cenobium.isti.cnr.it/) presents the various cloisters according to a user-friendly system of images and written information, video footage and 3D models. The arrangement of the capitals has been translated into a schematic diagram based on the ground plan, so they can be explored and viewed intuitively or via the accompanying text which explains what the images show and, along with the transcribed inscriptions, indexes the information and makes it searchable by means of keywords. The identification tag assigned to the individual capitals consists of two parts, with the first part indicating the cardinal direction and position; the second part takes into account an alternative numbering from the research references.

While browsing in the various cloisters, the user can also put together individual photographs or 3D models on the so-called LightTable, which allows to view the capitals of different cloisters side by side, using interactive inspection functions (zooming for photographs and rotating and tilting for 3D models as well as the simultaneous illumination of models). By means of computer simulation, the latter imitates "advantages of torchlight illumination" for viewing sculptures, which Goethe already had praised during his "Italian Journey" in 1787 (Meyer 1989, 352-353).

Through a combinations of the technologies provided, users can inspect capitals not only up close, but also from all sides; this is a kind of analysis of the cloisters that is not possible *in situ*. However, while placing the individual capital in a context and allowing comparative viewing, this kind of analysis at the same time involves a separation of the object from its "natural surroundings". The video recordings made in the cloister of Moissac by the documentary filmmaker Pascal Rehnolt and integrated into the website are an attempt to counteract this isolation through the addition of another medium. The online viewing of digital images in high resolution is no longer a major problem, since multiresolution methods can be implemented quite easily, reducing loading times and implicitly contributing a bit to aspects of security and copyright. By contrast, the 3D models in high resolution are quite heavy and took very long loading times, so that at the beginning of the project they were shown only using reduced resolution models and a specific plug-in. In the process, users not only had to install a program on their computers (the 3D browser plug-in), but the low-resolution models also had to be downloaded and stored on the hard drive. Navigating the capitals in 3D and in high resolution, on the other hand, was only possible at locally installed "kiosk" computers which had a copy of the 3D graphics installed on their hard drives. This 3D visualization technology used in the early phase of the CENOBIUM project was developed on an open-source basis and was freely available for downloading at ISTI-CNR (Cignoni *et al.* 2008). But CENOBIUM has been an evolving system: various technologies and instruments developed in the context of EU projects participated by ISTI-CNR have been then feed into CENOBIUM, with the KHI-MPI covering the residual costs for the modifications required.

The photo campaigns were organized and funded by the KHI-MPI. Besides being used for the project, all images have also been integrated into the holdings of the Photothek, or Photo Library, at KHI-MPI, thus allowing them to be viewed online in the digital photo library (http://photothek.khi.fi.it/).

The preparatory work, such as the development of specific work flows for the photographer and the 3D scanning, the procurement of permits, the organization of the multi-week campaigns on site, is costly and time-consuming and requires patience. Once the 2D photographs and 3D scans are completed, the post-processing of the digital images, the writing and translating of the texts as well as the configuration and preparation of the newly added website begin. Even when the integration of additional or updated new tools is often done concurrently, the addition of a new project stage can take a couple of years.

Fig. 2 – An example of the Monreale cloister, west side, capital no. 8; left: the set of photos acquired; right: the related 3D model, produced with active 3D scanning technology.

2. Technological design of the CENOBIUM platform

2.1 *Technologies endorsed at the initial design stage*

The initial CENOBIUM system was designed more than 10 years ago, around 2005-2006 (Baracchini *et al.* 2006, 2007). Our belief was that multimedia resources were (even ten years ago) regular research instruments in the service of various potential users (art experts, scholars, students, amateurs, tourists, etc.). Yet those resources were usually scattered and not easy accessible. The acquisition of content for the planned case study started in 2006 with the digitization of the capitals in the cloister of Monreale. We opted to sample both high-resolution 2D images and 3D scanned models. We decided to digitize in 2D all capitals, while producing 3D models only of those that are more important based on artistic quality and impact as well as figurative value (Fig. 2). 2D digitization was planned to sample all capitals from the canonical 4-sides directions (four photographs taken from a direction orthogonal to the 4 lateral sides of each capital; in several cases, the sides of the capitals were also photographed at diagonal, 45 degree angles). Each photograph was taken by isolating the capital as much as possible from the surroundings and masking the major sources of reflected ambient light with foils of non-reflective material. In Monreale, Aosta and Cefalù the photographer used a digital camera consisting of a Sinar P3 (optical bench) and a 22 megapixel 54H back (sensor resolution 5440×4080 pixel), and in Moissac, Tudela and Estella he used a 39 megapixel Hasselblad H3D. Each capital side was illuminated with at least two flashlights. At the same time the camera position and the distance to the capital always remained the same. Photos were taken with multiple exposures and using colour calibration units. Raw images were post-processed to calibrate colour. The quality of the photographs also impacted the 3D models, as the latter will subsequently be "overlaid" (textured) with the digital photographs.

3D models of the selected capitals have been produced initially by adopting active 3D scanning, using a laser triangulation system (Konica Minolta VI910). In the case of the Monreale cloister, twenty capitals were selected for 3D acquisition. The on-site 3D scanning campaign took one week, and was followed by extensive post-processing work done remotely in the ISTI-CNR lab. Each capital was sampled at a density of c. 10 samples/sq.mm. with a sampling error lower than 0.05 mm. All sampled data have been processed using software tools developed by ISTI-CNR. Initially, those tools were isolated components, which have been incorporated later on in the MeshLab tool (Cignoni *et al.* 2008). For each sampled capital, we produced a master 3D model composed of around 4-6 million triangles.

Since we wanted to offer 3D models representing both the shape and colour of the original artworks, all 3D scanned models have been textured using as input the high-resolution photographic images acquired by KHI-MPI. The back-projection of those photographs over the 3D models and the subsequent mapping was performed again using ISTI-CNR technologies (Callieri *et al.* 2002; Franken *et al.* 2005). Colour information was encoded by adopting the colour-per-vertex approach.

This multimedia material was made accessible to experts and the public by designing the first version of the CENOBIUM system (Fig. 3a). This was initially implemented as a local system, a kiosk installed in the KHI-MPI in 2007. Even from the very first stages of the project we aimed at pairing the kiosk with a web-based system (to make the data accessible to external users). In designing the system we thus decided from the outset to support web technology as much as possible. Hence the specification of the basic information

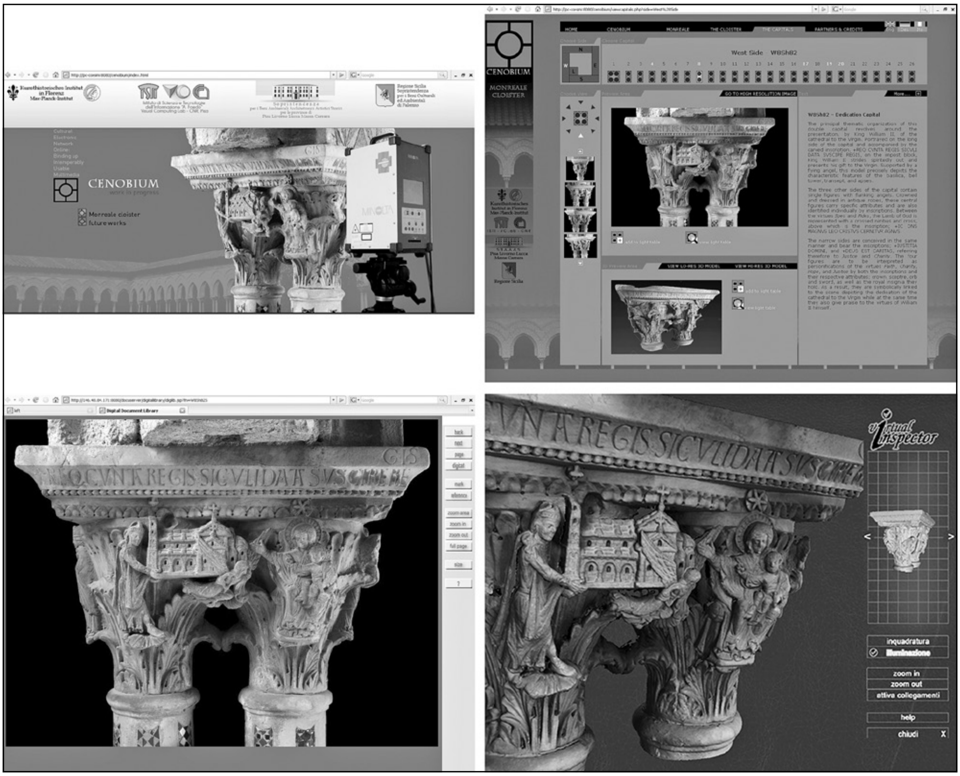


Fig. 3 – The first kiosk-based version of CENOBIUM; (a) the homepage of the kiosk; (b) the main page to browse and access the capitals of the Monreale cloister (note the buttons for activating the visualization of high-resolution images of 3D models); (c) the interface of the Digilib tool for browsing high-resolution photographs; (d) the Virtual Inspector tool for visualizing high resolution 3D models.

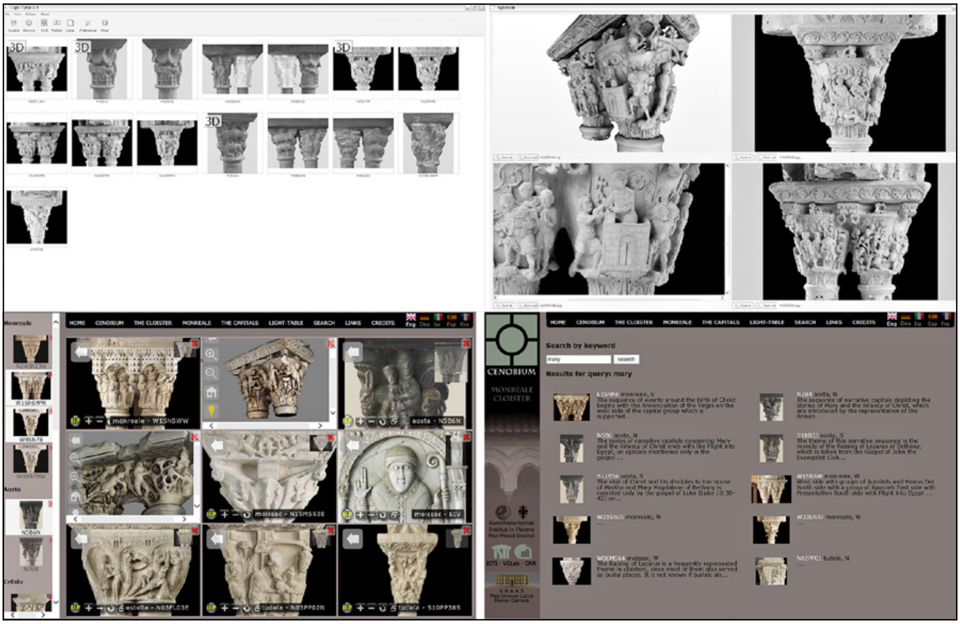
pages was implemented with HTML, thus using a standard web browser to manage the navigation of the content even in the first kiosk-based version of CENOBIUM.

The system interface is quite simple. The user may select a specific cloister directly from the CENOBIUM homepage (Fig. 1). Some standard web pages present the project, the selected cloister, and discuss how digitization was carried out. All multi-media information regarding each single capital can be explored in an integrated manner with the interface provided on "The Capitals" page (Fig. 3b). This web page allows the user to browse the capitals of the selected cloister by means of a stylized representation of the cloister, which appears at the top of the page. The capitals are arranged according to their spatial disposition in the real cloister (along its four sides), and the icon of the one selected is highlighted (e.g., in Fig. 3b the user has selected the west side of the cloister and the active capital is no. 8). The left part of the page contains interactive icons which allow the user to navigate through all the images acquired in the photographic campaign (users can view each requested image on the current page in low-resolution or, alternatively, open it at full resolution, see below). The 3D model was presented with a reference still image in the bottom of the capital page. In the first kiosk-based version, the visualization of the full-resolution multimedia data was implemented as follows:

– High-resolution 2D photographs were managed by adopting the image server Digilib (http://digilib.sourceforge.net/), which enabled local or remote visualization of high-resolution images (Fig. 3c);
– 3D models were visualized interactively by adopting the ISTI-CNR Virtual Inspector tool (Fig. 3d), supporting easy inspection and virtual manipulation of complex 3D models.

Another innovative component of CENOBIUM, already available in the kiosk version, was the LightTable tool (Fig. 4). This tool works as a shopping cart in an e-commerce website: the users select items (2D images or 3D models) during the navigation in the website, even from different cloisters. The selected items become the potential input of the LightTable tool which is aimed at supporting comparative visual analysis. It allows the user to put together individual photographs or 3D models in a single visual space and view the capitals of different cloisters side by side, using the interactive functions of zooming/panning for photographs and rotating/zooming and directed illumination for 3D models. CNR technologies are used for both image and 3D models visualization.

The architecture of the original kiosk version thus consisted of a number of web pages providing textual descriptions, and the pages providing access to the multimedia material as well as three applications (Digilib, Virtual



a b c d

Fig. 4 – The first kiosk-based version of CENOBIUM - the LightTable application, which uses a different screen layout to adjust to the number of visual objects selected by the user; (a) a set of digital assets selected by a user; (b) a session of the LightTable with four assets visualized (three images and one 3D model seen in the upper left panel). Below (c), the current versions of the CENOBIUM LightTable and (d) the query page displaying the results of a term-based search (in this specific case, the term “Mary”).

Inspector and the LightTable) inter-operating with a standard web browser. The overall organization of the related content and the structure created over the content were quite similar to the structure of the current CENOBIUM system. A major difference with the current version was the interactive visualization of multimedia files (2D images or 3D models), which was dependent of external applications (Digilib, Virtual Inspector and the LightTable). These applications were pre-installed in the kiosk version and prompted a change of context each time a user moved from a descriptive web page to the analysis of a single full-resolution visual document (from the web browser to the specific visualization tool and then back to the browser once the visual inspection session was terminated by the user).

2.2 *Ten years later: evolutions in digitization*

The acquisition of content progressed along with the life of the system. The initial Monreale testbed was followed by five acquisition campaigns, focusing on Aosta-S. Orso (Italy), Cefalù (Italy), Moissac (France), Estella and Tudela (Spain) (full content published between 2009 and 2018). Digitization procedures and technologies evolved considerably in the last ten years. We kept up with technological progress by adopting enhanced technologies (hardware and software) and revising our procedures. With regard to the acquisition of 3D models, we experimented new passive acquisition methods. The image-based approach by means of stereo matching was used to produce the 3D models of the Aosta testbeds (Salonia *et al.* 2009). We also experimented with newer and more accurate active 3D scanners (such as the GOM ATOS system). Finally, post-processing of sampled 3D data supported new algorithms, following the incremental updates and innovation proposed in the MeshLab tool and other software instruments. Major advances have been introduced in the course of the project: in the reconstruction from range maps, with the use of the Poisson reconstruction method (Kazhdan *et al.* 2013); mapping of colour data evolved (Callieri *et al.* 2008; Corsini *et al.* 2009), and new approaches were used for the simplification and multi-resolution encoding of the 3D meshes (Ponchio, Dellepiane 2016) also aiming at fulfilling the requirements of a web application.

2.3 *Ten years later: evolutions in web delivery and visualization of visual media*

CENOBIUM moved from the kiosk jail to the web in 2009 (Corsini *et al.* 2010). This was a major accomplishment, since our aim from the very beginning was to provide the service to the entire community of possible users. The first release of the web version included content from Monreale and Cefalù and it was very similar to the one already running on the kiosk computers. People interested in using the system on the web had to download and install three software components (Digilib, Virtual Inspector and the LightTable).

The Virtual Inspector tool was expanded to work on the Internet by introducing a component required for on-demand transmission of the multiresolution model to the remote rendering client. The same applied to the LightTable which was redesigned to allow each requested item (high-resolution photos or 3D models) to be downloaded on a remote computer.

Another major subsequent landmark in CENOBIUM life, occurring in 2012, was the extensive redesign intended to adapt the system to new developments in HTML5 and web-based renderings (WebGL). WebGL is a cross-platform web standard for 3D graphics, exposed through the HTML5 Canvas element. It allows 3D models to be rendered on standard web pages, without requiring the installation of plugins and it is now supported by all commercial browsers. The introduction and consolidation of the standard WebGL library provided the possibility of removing the three plug-in applications devoted to visualization (Digilib, Virtual Inspector and the LightTable), implementing their functionalities inside standard web pages. This was a major advance, as the need to install specific software components to just see the content of a resource linked by a web page is a main reason for abandoning the navigation. This is especially true in fields that tend to be less literate in computer-related issues and technologies, such as Cultural Heritage (CH) or Digital Humanities (DH).

In 2012 we therefore started a radical re-design and a new implementation of the visual components of the CENOBIUM system (Fig. 5). This was part of a larger research project which led to the 3DHOP platform (Potenziani *et al.* 2015). 3DHOP (3D Heritage Online Presenter) is an advanced solution for easy publishing 3D models on the web. It has been expressly designed to facilitate the accessing, spreading, and sharing of high-resolution/high-fidelity 3D models of real CH artworks, presenting them directly inside HTML pages. 3DHOP allows a performant and intuitive web exploration over high-resolution 3D models, mixing a powerful multiresolution streaming and rendering engine with a user-friendly interface. Hence the re-design of the CENOBIUM pages devoted to the visualization of 2D images and 3D models including transferring a number of methods and technologies designed for the 3DHOP platform to the CENOBIUM platforms. We decided to develop a new component for the visualization of high-resolution images, aiming to providing an integrated management of the visualization component both in the capital visualization window and in the LightTable (so as to provide a unique interface in both cases). This was implemented by adopting the IIPImage server, a tile-based solution that allows users to navigate and zoom in real-time large images, initially by means a Flash client which was subsequently replaced with a more standard HTML5 interface (Fig. 4a).

The second main addition was the adoption of the 3DHOP multiresolution rendering engine, which employs on-demand progressive transmission of the data to optimize transmission lags and to provide prompt visualization (since data are visualized as soon as they are transmitted to the remote client; the data resolution of the model presented to the user improves progressively as the data are received). Each single view the system retrieves from the server (and transmits over the net) only the pieces needed for the current view, at the most appropriate level of resolution. The result is a fast and immediate visualization, starting with a low-resolution representation which is automatically refined as the user explores the model. The original Nexus multiresolution rendering engine, adopted in Virtual Inspector and originally coded in C++, was completely rewritten in JavaScript to run on the web, becoming a core component of 3DHOP. Major revisions have been also introduced into our data streaming component, first in the 2012 version and more recently in the latest version released in 2016 (Ponchio, Dellepiane 2016). The latter also

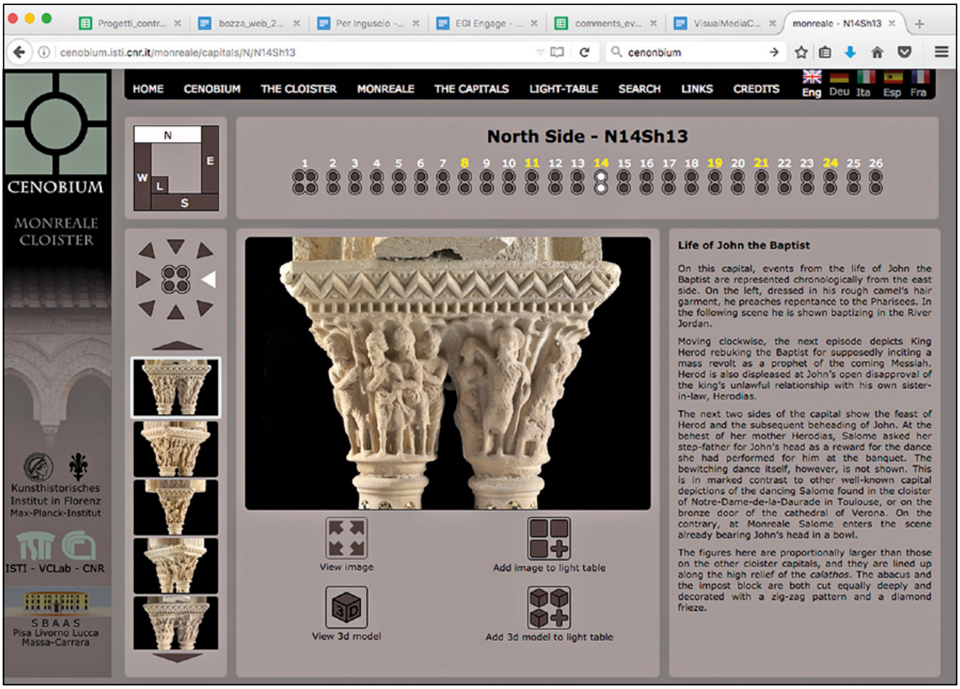


Fig. 5 – The current interface for browsing and selecting capitals in CENOBIUM (web version, available since 2012).

entails improved compression and decompression algorithms working over the geometry files, which contributes to the optimization of the data transmission time. Moreover, the rendering engine has been expanded to support the management of 3D textured meshes (while the rendering engine used in Virtual Inspector was only able to render 3D meshes with colour-per-vertex encoding).

Another new feature added to CENOBIUM in 2012 is the *search by keywords* page (Fig. 4d). The term(s) typed by the user is matched with a large set of terms defined while adding metadata to each capital. For each single item (capital) represented in CENOBIUM, the platform allows users with editorial rights to specify terms/tags which qualify the specific capital; these tags can be introduced in several languages (English, German, Italian, French and Spanish) and are part of the content stored in the CENOBIUM system. Once a normal user accesses the Search interface, the user enters the search terms and the set of results is presented by listing the name of the related capital(s) that match the search, the link to the respective page(s) and a representative iconic image for each resulting item.

3. Discussion and evaluation

The wide range of applications of CENOBIUM for research, teaching and cultural heritage preservation, as well as in museum or pedagogic contexts, is reflected in the frequent references to the project in monographs on the various cloisters, in the use of the photographs in scholarly publications (as reported in citations or acknowledgment text) and in the website statistics which might also indicate didactical use in seminars.

Some figures on the geographic locations of CENOBIUM users are shown for the time period 2014-2016. About 60% of users are returning visitors. Going back of the issue of potential didactic use, if we restrict the analysis to the location data of just 2016, we find that Canada (22.5%) was a close second to Italy (22.8%). Users from Germany, England and Spain ranged between 8% and 10% and users from the USA, France, Russia and Austria between 3% and 4%. The large number of users from Canada in 2016 may be explained by intense use of CENOBIUM as a didactical tool, as we noted that accesses from Canada in that year were from two universities located close to one another. Many scholars used CENOBIUM for studies in art history and mentioned the website in their publications or wrote articles about the project from a user's perspective (e.g. Klüver 2009; Hommers 2010; Kaufman 2011, 51-52, 356; Domaine, Vallet 2011; López-Menchero Bendicho 2013; Queyrel 2014, 10; Cusimano 2014; Dercks 2015).The project has been presented in numerous conferences and meetings devoted to medieval studies, cultural heritage and computer science (*inter alia* Baracchini *et al.* 2006; Corsini *et al.* 2010; Dercks 2008, 2012; Dercks *et al.* 2012). Aside from these publications, several presentations of the CENOBIUM project were made: in the 2008 exhibition "Sicily. From Ulysses to Garibaldi" Bonn and the 2010-2013 exhibition at the German Museum (Zentrum Neue Technologien) in Munich, at the 2010 International Congress on Medieval Studies in Kalamazoo, MI, at "Moving in Three Dimensions" 2012 Conference on Sculpture and Change at the Courtauld Institute in London, at the closing event of the 2013 project BW-eSci(T) in Tübingen, at the 2014 "DigitalSpecimen" conference in Berlin. They have shown that the objectives of the project have been met. According to both interested laymen and academic experts, this way of presenting and accessing multimedia data related to the capitals is useful and has great potential for conducting in-depth studies.

But just as photography is no substitute for the study of the artworks on site, 3D models do not replace the actual objects; the aim is, instead, to make an additional, if not different, instrument available to research. A complete inventory of the Romanesque cloisters is not the intention of the project. CENOBIUM is conceived as a work-in-progress where the integration of new technologies and contents is part of the program and based on the cooperation of two different disciplines, art history and informatics. New impulses from research in both fields are mutually absorbed. The potential for innovation is thus in the interest of both partners, in order to tap new ideas from the inspiration and the capabilities the other offers. The expansion steps and improvements proceed in waves, with the number of cloisters as well as the type of applications being continuously expanded in order to enhance a functioning VRE.

As we already mentioned in the Introduction, CENOBIUM should be a platform allowing any research lab or conservation institution to add content. This is by no means complex technically (we can easily ingest data produced by third parties, and we may grant "curatorial" access to any other selected contributor and allow a user to add related metadata and descriptive texts). Sometimes, however, it does become complicated, because a democratic and open attitude to the distribution of good quality multimedia content is still not common. In a few cases, we tried to convince colleagues to share the results of a 3D scanning campaign featuring one of the cloisters we have selected, unfortunately without success. Of course, the production of good quality visual content costs money and effort. But in some cases, owners of digitized data have an exaggerated sense of ownership over the results (especially when considering that in most cases those digitization efforts were fund with tax-payers' money). The DH community should offer a contrast to this type of approach by pushing the strong advantages of the open data approach. Moreover, we probably need to do more than cite and offer gratitude to those who share data on open platforms. Doing so should be rewarding for data producers as well. Like most, if not all, other scientific institutions, we cannot offer money for this. The reward should be scientific in career evaluation for example, we need to start taking into account and give proper weight to the efforts undertaken by a scholar in sharing results and digital resources incorporated in his research activity. Data should be treated the same way as papers, with proper indicators (citations) of who is using them.

3.1 *Plans for the future*

Firstly, we are planning to increase the number of capitals in cloisters and museums in France and Spain. An interesting challenge could also be the virtual reconstruction of cloisters that are no longer extant or that have undergone extensive rebuilding and can now be usefully compared with capitals preserved in museums, just as it may be possible under certain circumstances destroyed structures.

Secondly, we are planning to extend the technology behind CENOBIUM by:

– increasing the flexibility of the 3D models rendering engine. One possible suggestion is to allow removal of the colour/texture from the rendered 3D

mesh, in order to be able to visualize the digital model using only geometry, thereby providing a more informative view of small-scale shape variations;
– adding buttons in the GUI of the 3D viewer for the selection of prescribed standard views (e.g. the canonical four-side views);
– expanding the viewing experience by adding more features to perform shape-based analysis of the 3D models, such as interactive measuring features (point-to-point distances).

Finally, a redesign of the website that is under implementation is aimed at making CENOBIUM a *responsive* website. CENOBIUM was designed 10 years ago to conform to standard computer screens and thus to support a standard page size (1280*1024, i.e. 5:4 aspect ratio). The goal now is to allow resizing and using the screen aspect and resolution of different devices (tablet screens, smartphones, or very high-res computer screens).

4. Conclusions

The initial aim of the CENOBIUM project was to cater to different user populations and their particular needs: academic research, conservation of historical monuments, teaching as well as the curiosity of amateurs. This original objective has remained unchanged and served as the driving force in the evolution of the system (moving from an institution-confined resource, to a system freely accessible on the web). It also provided and consolidated a model for the effective cooperation between heterogeneous, international organizations and research institutes. The CENOBIUM project is an example of a successful cooperation between two very different disciplines: art history and computer science. The aim is for impulses from the research of both disciplines to mutually enrich one another, in order to visualize the research materials on the one hand and highlight the findings and interconnections between them on the other. Therefore, a main aspect of the CENOBIUM project is the shared interest of the two main partner institutions in creating a joint platform, maintaining it over time and developing new ideas by drawing on each other's inspiration and potential. This goes beyond the usual time limits associated with the life span of a specific funded project.

So far CENOBIUM has been supported in an implicit manner by many funded projects (mostly related to technology innovation and funded by EC); the technological transfer of the related results has been the focus of the (limited) funds specifically dedicated to CENOBIUM. We are convinced that this approach works quite well: short-term projects (with a finite duration, e.g. three years) should be devoted to specific technological innovation goals; longer-term projects should be devoted to the technological transfer to the CH/DH community and the consolidation of good practices. The latter are usually much less demanding in terms of dedicated resources (as was the case with CENOBIUM) and could provide ideal instruments not only for assessing the effectiveness of new technologies, but also to produce durable results and consolidate the use of specific platforms in the CH/DH domain.

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CENOBIUM incorporated results and technologies produced by several research projects: the early prototype was based on the outcomes of the EC "ViHAP3D" project; more advanced scanning technologies and visualization instruments, outcomes of EC 7thFW IP "3DCOFORM" and EC 7thFW NoE "V-Must.Net", were incorporated into CENOBIUM at a later time.

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ABSTRACT

The Authors present CENOBIUM, a web-based system designed to support the work of art historians. It provides access to multimedia content and related descriptive text on a specific topic: capitals in Romanesque cloisters. This paper discusses the motivation behind the decision to develop this web resource, taken more than ten years ago. It describes the initial design of the often system and how it evolved to keep pace with technological developments. In a context where the results of ICT & CH projects (digital tools, websites) have life span barely exceeding the timeframe of the actual project, CENOBIUM can be considered a success. It has been operating and steadily been updated with new content and latest technologies throughout its decade-long life.