

The Digital Archive of Sculptures of Tien-Shen Poo in Early Taiwan History

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Abstract. The traditional sculptures with posture and beauty are created by the fingers of sculptors, and these traditional techniques cannot be replaced by contemporary computer technologies. However, based on the development of 3D scanning technology, computers have more influences on sculptures. In terms of preservation, the sculptures can be permanently preserved in the form of a computer triangular mesh surface, which could be stored and distributed in any digital formats, and also can be replicated by rapid prototyping or computer automatic cutting. The aim of this project intends to permanently preserve four serious sculptures of a famous sculptor, Mr. Tien-Seng Poo, from the early Taiwan history. In addition, this project is not only proposing a standard process from 3D scanning to texture mapping, but also demonstrating some applications of exhibition, such as virtual reality, augmented reality, and rapid prototype, at the end of this project.

Keywords: Digital Archives, 3D Scanning, Virtual Reality, Augmented Reality, Poo Tien-Seng.

1 Introduction

In the past decade, there are more and more organization of governments and educational institutes interesting in preserving historical and cultural heritages around the world by varieties of methods and devices. The major methods and equipment for documenting and surveying of historical and cultural heritages are: traditional manual methods, topographic methods, photogrammetric methods, and scanning methods [1]. Real 3D objects can be reconstructed automatically by using 3D scanning methods with the significant advantages of their high accuracy in geometry measurements [2]. Moreover, Blais [3] has evaluated various commercial range scanning systems. In General, most of the scanning methods demand a series of sequent steps for object geometric and texture acquisition and registration.

Due to the well-developed of 3D scanning technologies in contemporary computer graphics [4], a variety of 3D scanning methodologies have proposed major solutions for generating realistic detailed 3D replicas. Real objects or elements usually could be scanned and formatted by using triangulated meshes, supported by all commercial 3D graphics hardware and software. On the other hand, in the process of texture acquisition, Bernardini and Rushmeier [5] have addressed some mapping techniques onto the

geometric model. By doing so, their method not only could exploit images of the object acquired by digital camera from different angles of viewpoints, and reconstruct the geometric model by using photogrammetry, but also is a low-cost and useful method when direct access to the object is not allowed.

Although several methods for 3D digitization could archive high geometric resolution of cultural artifacts, there are still some weaknesses of mapping high textural resolution on complicated historical objects, such as sculptures, for digital preservation and virtual exhibition. This project attempts to form a stand process from 3D scanning to high textural mapping for historical sculptures of a famous sculptor in early Taiwan history. Therefore, a complete process from 3D scanning of real sculptures to texture mapping of multiple-angle of viewpoints, and to virtual museum and their applications, will also be proposed at the end of this project.

2 Mr. Tien-Seng Poo

Mr. Tien-seng Poo is a famous deceased sculptor from the early periods in Taiwan. He is mainly famous his bronze sculptures of half-length portraits, such as the sculptures of the Father of Chinese, Dr. Sun Yat-sen, in front of Zhongshan Hall, the late president, Chiang Kai-shek, on Dunhua Road, Wu Feng in Chiayi, etc. By cooperating with Professor Hao-ming Poo (the eldest son of Tien-seng Poo), this projects uses 3D technology to digitalize and preserve the works of Mr. Poo. In addition, the “Virtual Sculpture Gallery of Mr. Tien-seng Poo” is constructed to exhibit the works of Mr. Poo, via virtual space.

Mr. Tien-seng Poo was born in Chiayi, Taiwan in 1912. At the age of 19, he went to Japan to learn sketching and painting Nihonga (one kind of old Japan drawings), and he eventually transferred to the division of sculpture. He was one of the earliest Taiwanese artists to study abroad in Japan. He created more than 200 pieces of sculptures in his life. The works in his early days, such as “Wife” (Fig. 1, left), created in 1941 for his wife in their second year of marriage, which presented simplicity and soft outlines textured in mud, and expressed his love for his wife.



Fig. 1. Left: Wife (1941, bronze 24×11×10cm); Right: Child Carrying A Dog (the third son carrying a dog, 1956, bronze 35×19×20cm)

Some of his works were inspired by his life, for example, Child Carrying A Dog (Fig. 1, right) was created during a leisure afternoon when Mr. Poo asked his third son, who was carrying a Pekingese, to remain still, and used mud to create the sculpture. Although it was an improvisation, the sculpture revealed good posture and smooth lines.

In 1996, at the age of 85, Mr. Poo completed his last piece of art, a memorial bronze statue of teacher Ching-chuan Lin. He spent four years, five months, and 15 days to create the work, which is now erected in Zhingshan Art Park nearby the Taipei Fine Arts Museum. Mr. Poo died of gastric cancer at the National Taiwan University Hospital on May 31 at the age of 85. He created as many as 223 pieces in his life, including the categories of family, personage, animal, outdoor memorial statues, a gymnastic series, and memorial head statues. The processes of the digitalization of 3D scanning required a great deal of labor and equipment; therefore, a total of 56 small-scale sculpture pieces were scanned first, including 11 pieces of family sculptures, 19 pieces of personage sculptures, 16 pieces of animal sculptures, and 10 pieces of the gymnastic serial sculptures.

Table 1. Statistical table of the works of Tien-seng Poo (arranged by Hao-ming Poo and Yi-chun Poo in July, 2006)

No.	Categories	Number
1	Family	11
2	Personage	19
3	Animal	16
4	Gymnastic	10
Subtotal (1+2+3+4)		56 scanned in this project
5	Outdoor	14
6	Body	63
7	Head	90
Total		223 total

The project for building the digital archive of Tien-seng Poo includes three stages. The first stage is the 3D scanning and digitalization of sculptures. The second stage is the 3D texture mapping. The final stage is the presentation and application of digitalized sculptures. The procedures of the project are arranged as follows: (Fig. 2)

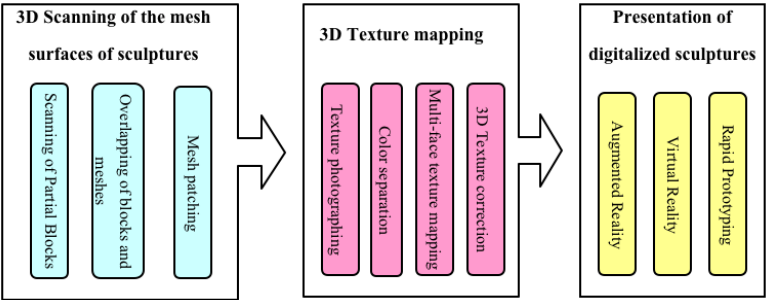


Fig. 2. Arrangement of the project procedures

3 3D Scanning of the Mesh Surfaces of Sculptures

The main purpose of the first stage is to employ 3D scanning technology to convert the sculptures into triangular mesh surfaces in the computer, which are permanently preserved, undamaged by time or environment. As for the process and technology of 3D scanning of sculptures, there are different operating procedures for different scanners. In terms of the project, the 3D scanning of mesh surfaces could be divided into four steps, namely, the scanning of partial blocks, adjustments of relevant positions of the blocks and meshes, automatic overlapping of blocks and meshes, and mesh patching.

3.1 Scanning of Partial Blocks

The 3D scanner utilizing in this project is Desktop 3D Scanner, made by NextEngine Inc. (<http://www.nextengine.com>) (Fig. 3). The scanning field is ranging from 5.1" x 3.8" (Macro) with 400 DPI to 13.5" x 10.1" (Wide) with 150 DPI. The dimensional accuracy are ± 0.005 " in Macro Mode, and ± 0.015 " in Wide Mode. In addition, there is no limitation on the size of sculpture by using composite-captured software, ScanStudio™.

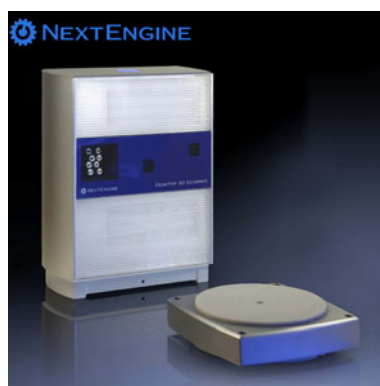


Fig. 3. Desktop 3D Scanner by NextEngine Inc. (<http://www.nextengine.com>)

Therefore, the difficulty in 3D scanning sculptures is that one sculpture cannot be entirely scanned in one step because it is a 3D object. Moreover, there is a restriction on the scanning area of the scanner itself. Therefore, in the scanning step of partial blocks, a sculpture would be divided into three or four layers in order to conduct a preliminary scan (Fig. 4, left). In addition, a single circle scan of each layer must be conducted prior to continuing with the next step of adjustments of positions. However, at present, some scanners are equipped with a mechanical device to rotate the object being scanned, which achieves the completion of scanning 3D mesh surfaces in one step. However, such scanners are very expensive.

After completing the scanning of three or four layers, there remained many faces that could not be scanned, such as the hindbrain and mandible of Fig. 4 (left), and many parts had to be rescanned alone by adjusting the scanning angles. After obtaining the

mesh data, and the meshes of specific parts by multilayered scanning, the adjustment of positions are conducted in the next step.

3.2 Overlapping of Blocks and Meshes

The second step in constructing the 3D mesh surfaces is to adjust the 3D spatial positions of the meshes of different partial blocks, and assembling them (Fig. 4, Right). The more advanced 3D scanning equipments, as mentioned above, could automatically assemble layers of mesh surfaces. However, the scanning equipment used in this project required more time to adjust the mesh surfaces prior to the automatic overlapping of computer formed circles of mesh surfaces.

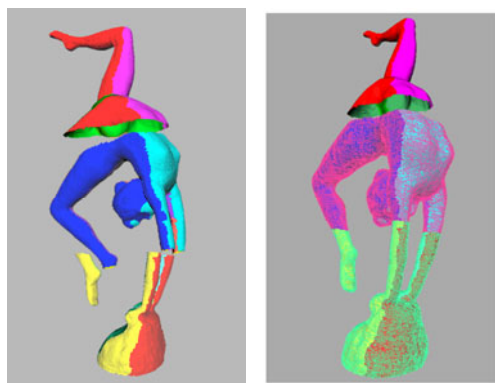


Fig. 4. Left: Scanning of three-layer mesh model; Right: Adjusting and assembling meshes

3.3 Mesh Patching

After the automatic connection of mesh surfaces by the computer, many meshes still lacked mesh data, which are known as broken meshes. Therefore, the major purpose

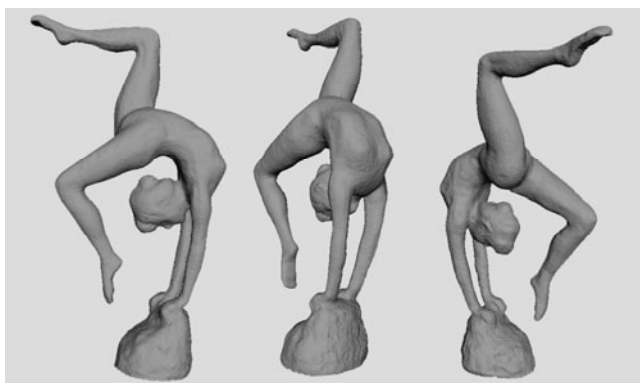


Fig. 5. Digitalized sculpture after the completion of scanning

of the final step of 3D scanning of sculptures is to patch the broken meshes. The deficiency in the mesh surfaces could be calculated by the mesh data surrounding the broken surface; however, meshing patching can only be used to patch the smaller broken surfaces. If a broken surface is too large, Step 1 must be re-initiated to conduct rescanning, readjusting, and repeat the overlap by computer. The entire triangular mesh of the sculpture is completed (Fig. 5).

4 3D Texture Mapping

After scanning of geometric mesh in previous section, the next step is to match high-resolution texture on the digitalized sculptures. However, all the relevant scanning equipment at present fails to deal with texture integration with different viewpoints during or after scanning mesh surfaces. Therefore, in this project, another 3D software application, Maya, is used to conduct texture mapping, as different 3D editing software has different procedures and effects for texture processing. According to the test results of this study, the effects of Maya software were the best. Therefore, Maya software is used for the stage of texture mapping, which includes the steps of texture photographing, model import, color separation, texture mapping of six faces, and texture correction of 3D painter.

4.1 Texture Photographing

In the first step of texture mapping, in a studio with good lighting, the five cube faces of the sculpture are photographed first, namely, front, back, left, right, and top, respectively (Fig. 6), which are photographed under the simulated lighting of the actual exhibition space, with a high resolution professional digital camera. In order to reduce the weight of the sculpture, most of the sculptures are hollow; therefore, there is no need to photograph the bottom of the face.



Fig. 6. Photographs of the front, back, left, right, and top face surfaces from a front view

4.2 Color Separation of the Model

After taking pictures of the five faces of the sculpture, the high-density mesh model from the previous step is changed to a more appropriate mesh number. The file is converted to the .obj file format and imported to the Maya software to conduct the texture mapping of the five faces. During the process of texture photography, the front

plane projections of the x, y, and z axis are used as a baseline, in order to facilitate the use of texture mapping in the current step. Therefore, prior to the mesh model being imported to the Maya software, the color separation of textures is first conducted. The blocks for color separation are determined by the shooting angle of the front, back, left, right, and top faces (Fig. 7).

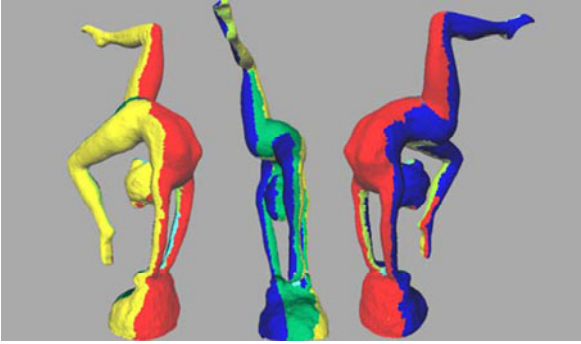


Fig. 7. Blocks for color separation of the model

4.3 Multi-face Texture Mapping

After completing the color separation of the model, the texture mapping from the five photographed faces is imported to the 3D software in order to conduct multi-face texture mapping. During the mapping, the texture mapping of the five faces is set for different textures and properties, and is mapped to different colors according to the color separation model of the previous step. However, it takes time to adjust the mapping in this step as the computer cannot automatically determine the relationships between textures and mesh surfaces (Fig. 8, left). It could be inferred that it requires the human eyes to determine and adjust the mapping texture to the position of the mesh surfaces. After each multi-face texture is adjusted, the multi-face texture mapping step is complete (Fig. 8, right). However, there could be problems with uneven lighting or seams among the different textures, which are solved in the next step.

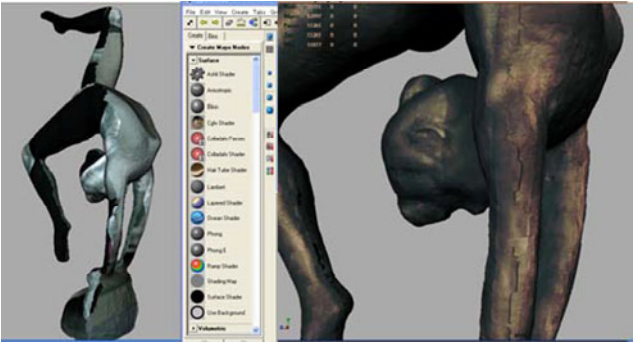


Fig. 8. Left: Mapping textures of different properties to different mesh surfaces; Right: Completed graph of multi-face texture mapping

4.4 Texture Correction of 3D Painter

During the texture photography of 4.1, multi-angle pictures are taken from the front view without changing the light source, which is in an attempt to simulate the exhibition. However, in 3D software, after different pictures mappings are imported, there remains an unevenness of multiple textures or significant seams (Fig. 9, left). The 3D painter of the 3D software can patch unevenness and seam textures of similar colors by using the spray gun. The final step is the completion of the texture mapping of the entire sculpture (Fig. 10).

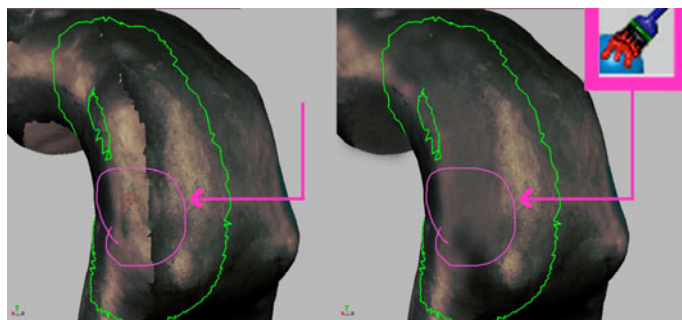


Fig. 9. Left: Unevenness and significant seams among different textures; Right: Textures after correction

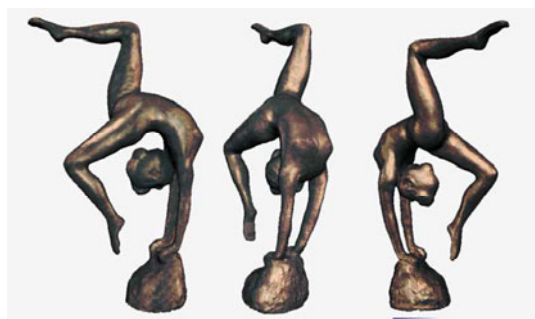


Fig. 10. Completion of the texture mapping of the entire sculpture

5 The Digitalized Sculptures

In this project, we have completed 56 pieces of sculptures by 3D-scanning process in previous section. There are four series of sculptures, including Family, Personage, Gymnastic, and Animal series. All of them have been scanned in this 3D-scan project. The following sections are representing them after 3D-scanning and texturing in 3D software.

5.1 Family Serial

There are 11 pieces of sculptures in the Family serial (Fig. 11), which are about family members of Mr. Tien-Seng Poo, including his wife, mother, father, sons, daughters...etc..



Fig. 11. The 3D-scanned and texture mapped sculptures of Family serial

5.2 Personage Serial

In this Personage serial, there are several famous people in Taiwan and China histories (Fig. 12), such as Dr. Sun Yat-Sen (P_10, the Father of R.O.C.), Confucius (P_11), Wang Chen-chu, (P_12, the first Taiwanese playing baseball in Japan)...etc..



Fig. 12. The 3D-scanned and texture mapped sculptures of Personage serial

5.3 Gymnastic Serial

Mr. Tien-Seng Poo was familiar in expressing the details of human postures (Fig. 13), and animals (Fig. 14). In this project, there are 10 pieces of Gymnastic serial and 16 pieces of Animal serial (next section), respectively.

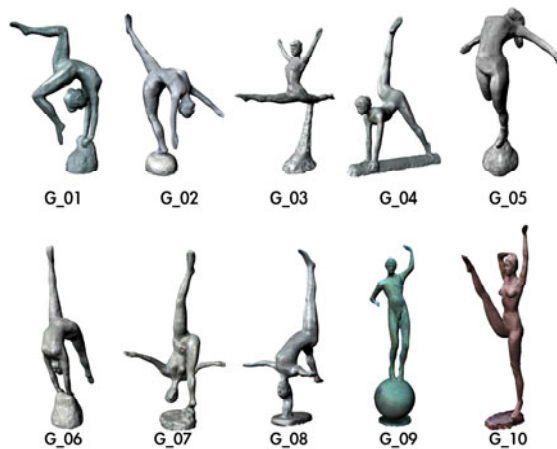


Fig. 13. The sculptures of Gymnastic serial

5.4 Animal Serial

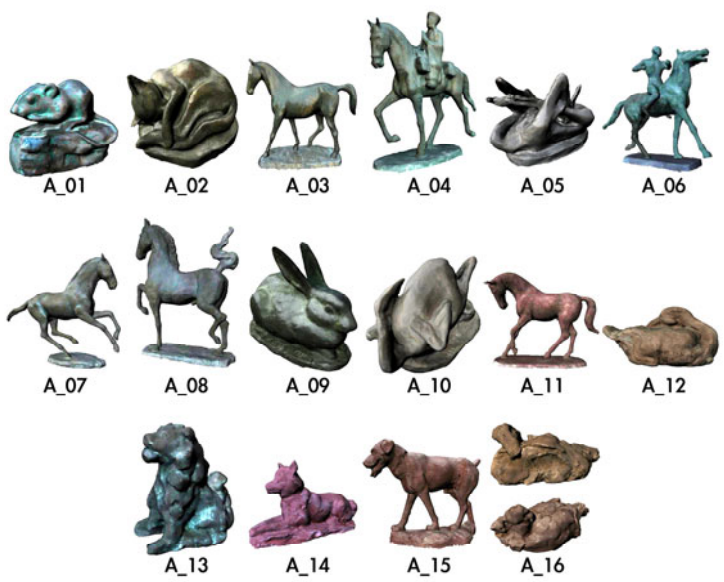


Fig. 14. The 3D-scanned and texture mapped sculptures of Animal serial

6 Presentation of Digitalized Sculptures

In terms of the presentation of sculptures after digitalization, different technologies have different presentation methods [7]. Three different technologies are used to present the sculptures of Mr. Tien-seng Poo, including augmented reality, virtual reality, and rapid prototyping. However, this project is focusing on the introduction of digitization process from 3D scanning to high solution texture mapping. We only briefly illustrate the results of three kinds of presentations, but not the details of them.

6.1 Augmented Reality (AR)

In an augmented reality environment, users can use the Head-Mounted Display (HMD) to watch the digitalized sculptures in a real environment. In addition, users can change visual angles and distances to watch the digitalized sculptures. The exhibition of augmented reality is constructed based on the augmented reality environment software “ARToolKits” developed by “HIT Lab” of the Washington University. The digitalized 3D sculptures are presented through stereo glasses, with the training of image identification and real-time 3D display [8]. In this way, users can freely change the visual angles to watch sculptures at different angles. With the changes in distance between users and images, the details of the sculptures can be observed. Therefore, as opposed to general exhibition environments, users can closely interact with the sculptures.

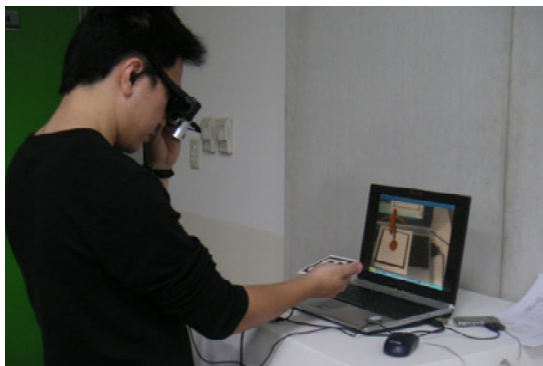


Fig. 15. Exhibition environment of augmented reality (AR)

6.2 Virtual Reality (VR)

In the virtual reality of the big screen, after computer-generated imagery is utilized to digitalize the actual exhibition scenes and sculptures, the computer-simulated exhibition space of the actual environment enables users to feel “immersed” [9]. Two projectors simulate two images of binocular disparity, which it projects onto a 210cm x 300cm large-scale screen. Then, wearing polarized 3D glasses, users can manipulate a wireless remote control of the virtual reality system environment to move freely within the virtual exhibition area, for a feeling of being immersed in the virtual space with the 3D sculptures.



Fig. 16. Exhibition space of virtual reality

6.3 Rapid Prototyping (RP)

Current reverse engineering is introduced by the field of product design, and has considerable applications in different design fields, such as architectural design and accessories design. In addition to digitalizing the sculptures of Mr. Poo, another major purpose of this project is to promote the art of sculpture through digitalized sculptures. Therefore, in addition to exhibitions in real and virtual spaces, another approach, called rapid prototyping, is used to replicate the full or reduced size of digitalized sculptures in order to achieve the effects of promotion.

In addition, during the process of creating sculptures, each piece of work is unique, and even when a sculptor replicates a work, the replication cannot be the same as the original. However, with the technology of rapid prototyping, identical sculptures can be replicated, in both reduced and full-sized sculptures for different needs.



Fig. 17. Rapid prototyping

7 Conclusions

Consequently, in order to digitally archive of the sculptures of Mr. Poo through 3D scanning technology, the standard procedure for 3D geometric scanning and high-resolution texture mapping are presented in this project. Although the 3D scanning technologies are well-developed for commercial purpose, digital preservations of

historical and cultural heritages are still labor and time consuming works depending on varieties of target heritages. Moreover, three different technologies in this project are used to present the digitalized sculptures.

Furthermore, with the release of new scanning technologies and equipments, the efficient and accuracy can easily be promoted, and updated software functions may make it more convenient to operate the software. Such new technologies, platforms of virtual reality, software, and presentation methods may be more suitable for exhibiting virtual sculptures, and present research directions for aggressive future investigation.

Regarding future research directions, in addition to constructing the virtual gallery for the digitalized sculptures of Mr. Poo, presented via the internet platform of virtual reality (e.g. Secondlife), this study aims to enable the global neighborhood to observe and appreciate the sculptures of Mr. Poo, under a variety of preferred circumstances, such as hosting a simultaneous global press conference.

Acknowledgements

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E.Stone, an Archive for the Sardinia Monumental Witnesses

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Abstract. The “E.Stone” project is based on the survey, documentation investigation and physical, geochemical and petrographic characterisation of the great zoomorphic and phytomorphic stones of Sardinia. The name chosen to indicate this project means the full value of these stones, standing before the beginning of human history. The main task of this project is to survey and to document, with an accurate laserscan survey, supported by topographical survey and integrated by GPS tracing and photographic and photogrammetric survey and supported by specific investigations on the rock characteristics. The further development of the collected data will be aimed to the definition of a digital “state of the knowledge” about the stone. This research will produce two main benefits: the creation of a clear and stable archive of these monuments and on the second hand will create the possibility to reply at any distance, a copy in any material of the original item.

Keywords: Stones, Sardinia, Landscape, Laserscan, Survey, Geology, Decay, Modelling, Documentation.

1 The E.Stone Archive

1.1 Background

In the world of humanity there are two kinds of processes which are always present: the natural processes and the anthropic processes. These manifestations taken different times and conditions to evolve; some of these mutations are clearly visible in a human lifetime, others take few instants, while certain requires millenniums or even millions of years to complete their cycle. In this way if we think to a stone on a seaside, sculpted by the sea and by the wind, it comes immediately clear how long it will remain at its place and in its conditions if compared to a bare foot impression left by a man on the sand: the simple human sign will have a duration of some seconds or maybe of some minutes, the first wave will erase the trace. But even with this meaningful difference, in our time we are able to damage or even completely demolish the whole patrimony of monumental rocks which is richly present in the Sardinia Island. Sardinia is the larger Island in the Mediterranean Sea and is the place some meaningful natural masterpieces, in some

cases this curious and fascinating stones are enriched by the work of men (like it is for the Elephant Stone where some “Domus de Janas”/“Fairy House”, a specific kind of ancient tombs, were carved in the prehistoric age). The fact that Sardinia Island shows very ancient rocks, with some formation coming from an age far more then 500 millions of years from our time, create a great emphasis about these stones, giving to the observer a great impression which goes far behind the simple surprise happening in front of some natural wonder.

The name chosen for this project is “E.Stone, an Archive for the Sardinia Monumental Witnesses”, the reason for this choice are first of all linked to the specific approach to the research, which is based on advanced digital tools, so the “E” of “Electronic” is placed in front of the word “Stone” written in English also in the Italian version of the name to underline the intention to share and to disseminate these contents at an international level. The term “Witnesses” is used according to the word often used in geology to refer to the rocks testifying a previous condition. The use of the term “monuments” should be understood in its value described in the definition of the Treccani vocabulary: “[...] to indicate what, for its size, is giving an impression of grandeur and solemnity [...]”.



Fig. 1. The stone and the footprint, two different times

1.2 Documentation and Dissemination

To allow the preservation of these monuments the first step is knowledge, but not only as a theoretical work ending in itself but as a passage of awareness based on a dissemination process. The tools available today make it easier and more versatile than ever before. In this way, this particular monument will be treated like they deserve, like any

other monument from the earth heritage, giving to the "monumental witnesses" their right value and preserving their memory from the risk of deterioration and decay, creating the right conditions for knowledge and protection.

The digital survey tools and the advanced investigation solutions combined with high-tech multimedia presentation may found in three-dimensional modelling the right place to be focused, with the opportunity to realize different levels of learning. The creation of a repository of knowledge based on accessible criteria and three-dimensional access, will in time allow to repair or even to rebuild, if necessary, even when the monument should be seriously damaged.

Procedures based on a wide digital approach, from a massive use of laserscan survey to the digital modelling aimed to produce multimedia contents, can simultaneously be a process of effective disclosure of this environment, allowing users from all over the world to view, study, explore these monuments and learn more about the territory that they have all around.

The possibility to use both the current prototyping techniques to produce partial or total reproduction of these items in different material can operate in three main areas: the creation of "spare parts" for the monument, the reconstruction of the monument, and the easy and effective deployment in museums, exhibition areas or schools where the visitor will be able to touch the shapes of the monument. (and this will be a great occasion for the blind or visually impaired as well as for the people with normal sight), in this way, developing well oriented models, it will be possible to disassemble, to understand, to build innovative learning paths based on digital/physical models.

1.3 Decay Analysis for the Monumental Witness

Through the study of the geomaterials which are the natural constituents of the monuments of high historical and cultural significance examined here, it will be possible to evaluate the state of alteration and the causes that may have led the chemical and physical alteration. The intent will be to further investigate these issues, trying, on the basis of the results, to propose strategies for the conservation operating before then any catastrophic issue can take place. Operationally, all the monuments will be studied in detail about their minero-petrographic and physical characteristics, including various forms of macroscopic alterations and their distribution in the same monuments.

1.4 The E.Stone Project

If adequate resources will be found, the project will develop a first program of one year, at the starting phase of the project it will be immediately activated an Internet space to allow collaboration between the research teams. Within the first six months of activity the main campaigns of survey and documentation will start, inclusive of sampling and study of geomaterials from the monuments, the archive will begin to be formed immediately and simultaneously, together with the progress of the treatment and study of the collected data.

A first task in the survey campaign will be the completion of the documentation about some of the main witnesses of Sardinia, including: Elephant Stone near Castelsardo (surveyed in 2006), the Bear stone in Palau, the remains of the turtle stone and of the other stones with zoomorphic or phytomorphic shapes around San Teodoro, the

remains of the Columns and Mushroom stone (this one surveyed in 2010) on the island of San Pietro (Carloforte), the red rocks of Arbatax, the "Pipe organ" of Guspini, Punta Goloritzè (Baunei), S'Archittu (the small arch) near Santa Caterina Pittinuri (Cuglieri), the monolith (also known as "the shaped cake") on the Pulchiana Mountains in the Gallura area, the San Giorgio's staircase in Osini. For each of these natural monuments it will be also catalogued and stored all the data on the compositional characteristics, state of alteration and possible methods of restorative intervention in case of the presence of strong chemical and physical deterioration.

As told before, the survey will be operated with the use of laserscan units, the use of phase-shift or time of flight technology, will be chosen according to the specific survey condition, certain monuments will require long range scanner to be completely documented, other will require an high level of detail from the close range, the advantage of the phase shift solution, which is capable to measure a range equal to a full dome (320 vertical degree and 360 horizontal degree) with an accuracy up to four millimetres collecting up to 200.000 points for each operative second, make this kind of laserscan very interesting to reduce the operative time, but when the operative range will need to operate from a meaningful distance, a slower, but more reliable time of flight solution will be used. The entire survey, conducted using even different tools will allow the full coverage of the investigated object. The survey will be linked to a specific topographic network, and then referenced on the national map, this will allow a solid archiving of the collected data and fully useful for all subsequent stages of processing and analysis. The main steps of processing the data will be made up by the development of traditional two-dimensional representations, views zenith, plans, elevations, sections, useful to present the object using representation solutions which will be easily understandable and communicable. After this phase, the survey data will be used to develop a three-dimensional digital surfaces model, with a procedure aimed to preserve the greatest correspondence between the collected points and the final result. These models will be useful for the analysis and the study about the surfaces and the shape of the object, they will be used to study specific functions and, when mapped with photographs, to create images of graphics rendering.

Starting from these models, a complex process of treatment of the data will produce a new series of three-dimensional digital models, designed for online viewing and implementation of multimedia products.

The stage of treatment completion will include the implementation of digital models for the 3D printing of physical models, produced with additive or subtractive processes with 3D printers which are becoming more common with. In this sense, the models allow users to access downloadable versions of the scaled digital model, using specific machines, to print and create scaled versions of these monuments.

The models will allow reproducing a copy in resin, PVC or other economical materials, depending on the technology available. The production process of a physical model can be very simple, and in most cases it is very economical. In this way, it will be possible to envisage the possibility of reconstructing an entire remote collection of the monumental witness. Any school or association in the United States, South America, Australia or Japan, will be able to receive digital data to start to build scale models or even real-sized models. This solution will allow also the access to this kind of monument to blind and visually impaired people, they will be able to experience and understand the shapes of these stones thanks to tactile models.

Considering the fact that three dimensional printing may still result a difficult operation to many users, the models will be prepared in a sort of "assembly kit" based on a sequence of sections, laser engraved with specific machines or simply printed with a common printer on paper to be transferred to appropriate thickness and then cut manually. So, starting from the digital model and following simple installation instructions, everybody will be able to get a scale models absolutely affordable and accessible to all.

E.Stone project, step 1: Setting up an Internet space for data sharing. At the beginning an Internet space will be activated on the network for sharing and collaboration between the research groups. In this way the data previously collected, bibliographic references, iconographic, photographic, geographic references manuals and all information useful for the development of the project, will be kept continually updated. In this collaborative space, based on classical protocols for remote sharing and video-conferencing will be possible to solve the main participation trouble among the groups. At this stage, only active members of research teams, will access to the complete materials under development. However a small part of the whole research, set up as a "preview" of the site will be activated to facilitate the dissemination of information about the ongoing activities.

E.Stone project, step 2: Defining a catalogue about the state of knowledge on the elements of the research. This important step will have a rapid development in the first phase of the project so it will be used to plan the survey and documentation campaign. This phase will be based on the development of an online database.

The creation of this catalogue will determine the complexity, scientific interest, conservation status, risk status and accessibility of each monumental witness.

E.Stone project, step 3: Starting the survey and documentation campaign, on-site sampling and analysis of geomaterials. During this phase an intensive campaign of survey will start. The operations program will bring the survey units to operate on various monumental witnesses. Regarding the study of geomaterials in the monumental witnesses, it is expected to develop individual campaigns, with duration up to some days for each of the monumental witnesses; in this time the study about the macroscopic characteristics of lithological materials will be done, the material samples will be collected and the forms of alteration detection will be performed. When one of the monuments of major importance will be the subject of the survey, a specific workshop / seminar will be organized, it will be opened to the local technical operators who handle land management (municipalities, provinces, Soprintendenze), scholars, students of schools and the professionals who work in Cultural Heritage and Landscape, as architects, engineers, geologists, archaeologists, surveyors, etc..

The operations of this phase will collect a huge volume of data and wide dissemination of the ongoing works.

E.Stone project, step 4: First morfographic data processing, information sharing. Once the phase of collecting information will be completed and treated to create an early accessible and "cleaned up" set of models, three-dimensional models laserscan, printouts, photographic and textual data will be made homogeneous according to common standards for the research groups, structured in accessible formats. In this phase, data collection will enrich the catalogue database of monumental testimony, with a substantial increase in the state of knowledge about these elements.

E.Stone project, step 5: The second stage of data processing (advanced models, physical model development). At this stage the treatment of data collected will be in its advanced phase, with the production of the first models aimed to multimedia broadcasting and public access through the project site. The production structure for the models will be organized around three main lines of development models: for online viewing with photorealistic features; models for specific information viewing (decay, thematic maps, etc ...); for 3D printing process solutions.

E.Stone project, step 6: Interpretation of data about geomaterials processes of change and proposals for the preservation of monumental witnesses. The handling and analysis on the collected data going to store them into the database system of E.Stone. In detail, all geomaterials which are in the selected monuments will be studied in detail, the geochemical characteristics (fluorescence, spectrometry, X-ray), mineral-petrographic (optical microscopy and X-ray diffraction) and physical characteristics. The analysis of materials will be mainly done on the outcropping geological parts which formed the area around and not directly on the witness. This study will define the causes and processes of ongoing deterioration in the each monument. A proposal about intervention strategies for restoration and preservation will be based on the results of this phase.

E.Stone project, step 7: Dissemination of Information. A version for easy reference catalogue of monumental testimony will be posted on the site of E. Stone. The section dedicated to access to three dimensional models and the section about multimedia materials will be inaugurated. The models will be set available for users of E.Stone, with the ability to request access to the specimens and recording. The information and the progress of research will be disseminated through the traditional forms of research and discovery of information from the Internet.

E.Stone project, step 8: Consolidation and management of the Internet dedicated space. At the end of the phase 7, the site of E.Stone will continue its growth by implementing a structure to make possible to access the Web geography resources (Google Earth and similar systems). The areas dedicated to individual monumental witnesses will enrich the discussion forum with the participation of users outside the project that this will contribute by adding their own images, reports, information about the "large stones of Sardinia" in this way users will be more involved in the site and will also give the opportunity to ensure a continuous update about the condition of the monuments, forming a sort of "public" monitoring.

E.Stone project, step 9: When the E.Stone website will arrive to complete the main tasks and to present exhaustive set of information about the monuments a series of seminars and workshops in the area. Will take place, the techniques, procedures and technologies used for the E.Stone research will be shared with activities on the Sardinia Island and with Internet based learning, the online seminars will be structured in such a way as to ensure maximum usability by different users (students, scholars, professionals, technicians). The double activity about learning, with direct workshops and online seminars will be done to allow the better dissemination of the results.

1.5 Expected Results

- Creation of an online documentation centre about the "monumental witnesses of Sardinia" that will determine the methods and a reference for the management and processing of this data.

- Creating an archive based on the logic of sharing and the continuous enrichment of the catalogue, integrating it with the continuity of training experiences like degree Thesis and Ph.D.
- Sharing and dissemination of knowledge; networking with other groups of scholars, to promote and enhance the state of knowledge and the state of the art in dealing with this category of heritage subject.
- Creating the conditions to allow a better approach to conservation and restoration of this particular stones.

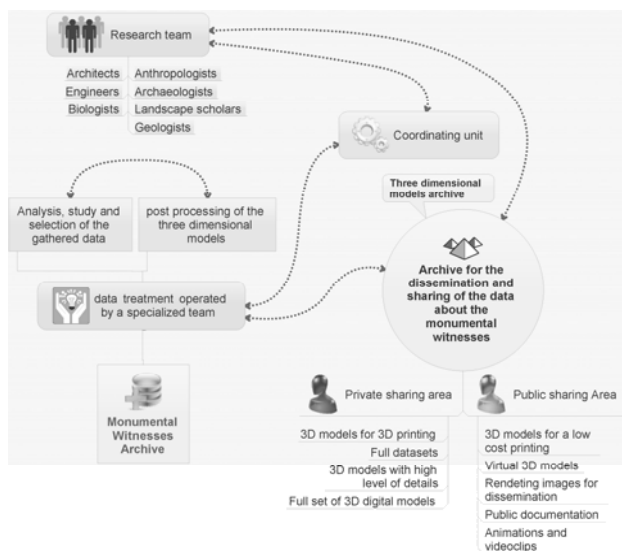


Fig. 2. Schematic view of the E.Stone archive project

2 What Was Done Until Today

At the time for this project/work two stone monuments were examined: the Elephant of Castelsardo (Anglona, north Sardinia) and the Mushroom of Carloforte (north of San Pietro Island, southwest Sardinia). For the first stone operations in the following activities were set up: 1) laserscan technology complete survey 2) study of various forms of macroscopic alterations and their distribution in the same stone; 3) removal of small sample from the stone monument; 4) experimental determination of physical, geochemical and petrographic characteristics of geomaterials by laboratory analysis, using many instruments: helium pycnometer, polarized microscope, electronic microscope (SEM), X-ray diffractometer (XRD), X-ray fluorescence spectrometer (XRF), etc.; 5) interpretation of first data of laserscan survey and laboratory analysis; 6) evaluate the grade decay and the causes of chemical and physical alteration of geomaterials. For the second stone, the work activities were limited only to the following points: 1), 2), 3) and 5). The end of this study, based of the results obtained, will be proposed strategies for the conservation of stone monuments.

2.1 Geomaterials and Geologic Settings

Planning The Elephant and the Mushrooms stones are big blocks of ignimbritic rocks of the Sardinian Cenozoic volcanism that forms a magmatic arc running along the western margin of Sardinia and southern Corse microplates (Lecca et al. 1997 and references therein). Volcanic activity, with a calcalkaline affinity *l.s.*, began in Oligo-Miocene (around 32.4 My ago; Beccaluva et al. 1985, Savelli 2002 and references therein) producing basaltic and andesitic lavas and ended about 13–11 My ago, showing a climax between 23 and 17 My. From 23–22 My onwards (Beccaluva et al. 1985 and references therein), highly explosive ignimbritic fissural emissions with dacitic-rhyolitic composition occurred simultaneously and with alternating basaltic and andesitic lavas in various parts of the island, mainly along the western graben. This volcanism, whose products crop out in vast areas of Sardinia, is generally related with a subduction of oceanic lithosphere in a N-NW direction along the European continental paleomargin that produced the Oligocene rift between Sardinia and Provence (Cherchi & Montadert, 1982). The volcanic activity preceded and partly accompanied the opening of the western Mediterranean sea through the formation of the Provençal Balearic and Algerian basins. This led to a 60° counterclockwise rotation of Corsica-Sardinia blocks around a pole located at 42.7° N and 9.6° E (Gueguen 1995).

2.1.1 Anglona Area

The crop out of Elephant ignimbrite is located in the northern of the Oligo-Miocene Sardinian Rift, in Anglona (north Sardinia). In this area three extensional phases can be recognized in this area during a fifteen million year period which spanned Corsica-Sardinia continental microplate separation and Western Mediterranean back-arc basin opening (Sowerbutts, 2000). The first phase, initial late Oligocene extension created a half-graben geometry with syn-rift clastic deposits shed locally from fault-bounded highs, passing laterally to lacustrine marlstones. Calc-alkaline volcanic activity subsequently predominated as volcanic centres developed along one half-graben bounding fault, producing voluminous pyroclastic and epiclastic material. Second phase mid-Aquitania-early Burdigalian extensional faulting, recognized from localized clastic syn-rift stratal wedges, truncated and subdivided the half-graben. The syn-rift sediments were sealed by a regionally correlated ignimbrite that in turn was offset by late second-phase faulting. Third phase extensional fault movement, which reactivated the original fault trend then occurred. The pyroclastic rocks of Anglona show a strong heterogeneity, as the result of different eruption conditions and emplacement temperatures (high- to medium- to low-grade ignimbrites). Scatter also depends on the different incidence of pumice, crystal and lithic fragments and matrix. Based on their volcanological the pyroclastic rocks were divided into two main groups: 1) pyroclastic flow deposits with high- to medium-welded grade (including lava-like ignimbrites), from poorly to medium porous; 2) pyroclastic fall deposits with low-welded grade (e.g. cineritic products), from medium to strongly porous.

2.1.2 Volcanic Island of San Pietro

The crop out of Mushroom pyroclastic rocks is located on the San Pietro Island (southwestern of Sardinia), completely formed by volcanic rocks belonging to the Cenozoic Sulcis complex (Garbarino et al. 1985; Garbarino et al. 1990). During the

final phases of Cenozoic magmatism (Arana et al. 1974), three important episodes of volcanism occurred in the area of San Pietro, characterized by the eruption of a peralkaline rhyolitic lavas and ignimbritic complex, interlayered in the products of a regionally extended calc-alkaline activity. In a first, has a calc-alkaline volcanism (older than 15 My) with a character fissural and led to the formation of lavas and ignimbritic deposits to regional extension. In the second phase, there is a type of comenditic volcanism, with the formation of lavas and peralkaline ignimbrites. The last phase will have a calc-alkaline volcanism, with the emplacement of products with textural aspects typical of pyroclastic flow.

The volcanic outcrops in the 'Punta delle Oche' (north island), where the mushroom stone is located, are ignimbritic rocks (with a calc-alkaline affinity *l.s.*), formed in the latter phase.

2.2 The Elephant Stone

Until laserscan technology, this monument was not really surveyable, the strange shape, the huge massive structure was a real problem for anyone who would try to realize a serious survey of the whole stone. Thanks to the laserscan technology this work became as easy as a complete photographic campaign. The older survey, published years before, was about the tombs and was a good work, but it was a simple, classical bidimensional set of drawings, moreover it was aimed to document only the ancient graves, and gave no information about the stone in itself. To face this work we choose to use a Leica HDS 3000 panoramic scanner, based on the time of fly technology. This was done for two reasons: for first this scanner is capable to gather a very accurate set of points from a very short distance and this was a very important feature to allow the survey of the inner parts of the graves. Secondly this scanner is also capable to gather a very accurate result from a long distance, so it was possible to place the scanner in the upper parts of the hill in front of the stone and take the survey of the upper parts with the same quality of the all the rest of the monument. To allow an high quality result in the overall operation the laserscan survey was supported by a complete topographical survey, aimed to build a specific network of all the special targets placed on the monument and absolutely necessary for a clean reconstruction of the single scans. It is important to remember that the use of a topographical survey is not only fundamental because of the high level of accuracy in the registration process and for the better and easier scanning planning; it is important because when the topographical network is planned, a series of permanent points are placed on the ground around the monument. Those special points can remain placed in the site for many years; so if there is the need for a new survey, for example if it happens that a part of the monument is damaged, or for simple monitoring needs, it is possible to have a really accurate comparing of the two surveys according to points which are external to the monument. In facts it would be possible to reply a new survey from any new position of the laserscan and there will be no need to have a complete new survey while also a single part of the monument can be measured again.

The new survey can be placed exactly on the old one according to the topographical survey, based on some of the old points left on the area during the first digital survey. In this way, having a reference system based on the general environment, allows to monitor any change not only in the shape of the stone but also in its position on the

ground. The survey was completed in two single days, twelve scan stations were operated, and the whole work was organized in three main development paths, one going around the stone, one for the long distance stations and a final one crossing inside the system of the lower tombs. In this way a good, almost complete coverage of the stone was produced and a large amount of the landscape around the monument was also taken. The overall pointcloud is made of almost twenty five millions collected points. The accuracy obtained was around six millimetres for each scans. When the scanner was placed inside the graves the use of a wireless access point was very useful to have a remote control of the scanner from the outside.

The topographical network was based on six topographical stations and took the survey of the almost forty targets applied on the stone and completely removed at the end of the whole scanning session.

2.2.1 First Data Treatments (Digital Survey Dataset)

The first step in the treatment of the collected data was, as usual, the registration of all the single scans in a unique digital model. This was done following two classical criteria for this kind of survey: for first the single pointclouds were registered over the topographical survey, then they are geometrically compared (using the “cloud constrain” function in Leica Cyclone) to improve the alignment of each pointcloud over the other.

After the registration, the first operation taken on the resulting pointcloud were aimed to produce some simple sections all around the monument and a first, simplified, surface model with almost all the occlusion holes fixed.

The whole first treatment was aimed to produce a massive, basic model of the monument. This was a first surface model useful to verify the quality of the collected data. On the surface digital model a first texturing treatment was applied to have a better evaluation of the result.

Bringing this model to generic rendering software like Maxon Cinema 4D allowed testing how was versatile the obtained model. Inside this software it was possible to produce a series of rendering view of the digital model and it was possible to use this environment to develop some 3D interactive simulations to allow a better sharing of the first result without the need to share the heavy and hard to manage surface 3D model. The 3D interactive simulations were developed using the Quicktime VR output, a pre-compiled system of visualization capable to bring the perception of a full virtual space, with a visualization based on a pre-calculated series of frames. The overall effect is quite good, allowing a good sight on the whole model and a quick exploration of the shape of the monument without any need of complex navigation systems. Obviously this was just a simple, first test to verify the quality of the survey, while the whole project is planned to achieve a more complex structure.

All the process is aimed to produce three main results, each result integrates the other:

- The first result is to have a very high quality survey of the monument, useful as a precious documentation of the conditions of the stone in the November 2006.
- The second result is to produce a set of popular and interpretative models to enhance the possibility of using and sharing of the knowledge about this important monument.

- The third result is to build a rich set of information, which will be available as a starting point for the enhancement of the knowledge of this ancient patrimony and as an incentive to the research about this awesome theme.

2.2.2 Final Data Treatments (Digital Survey Dataset)

The first part of the work over the data treatments clearly showed that an approach developed in a small simplification of the model can give a good looking result, but it is interesting only for shape analysis and monitoring purposes.

The time consuming rendering and the impossibility to use the high resolution model for real time access creates the need to face the modelling process in a new and specific way. So a different approach was chosen, no more direct modelling from the pointcloud, but a process starting from a new rebuilt and optimized polygonal model and then a reconstruction based on the subdivision surface modelling.

The following steps in modelling produced a variable resolution model, capable to switch gradually from a full resolution representation to a lower polygon representation, crossing all the intermediate steps of the representation.

The keywords for this process of variable simplification were: edge loop modelling, Re-Topology modelling. To greatly enhance the representation two advanced digital modelling and texturing solutions were adopted, the classical texture Unwrap procedure based on the photographical documentation campaign of the stone and a specific Normal Mapping procedure based on the information coming from the high resolution model in itself. In this way a whole new model was produced, not aimed to monitoring or accurate information extraction, but greatly suitable for multimedia and representation.

The software workflow for the developing of this new multimedia oriented model was based on Pixlogic Zbrush and Maxon Cinema 4D.

A The whole process was aimed to develop a specific solution for this kind of items, to produce a method to face and develop high performance models of rich shaped stones and natural monument, the case study operated on the Elephant Stone demonstrate the full opportunity offered by the method, capable to produce a high



Fig. 3. Rendering view of the three dimensional digital model of the elephant stone

level documentary model, useful to create an accurate memory of the real shape of the item and a versatile multimedia model, capable to adapt its level of detail to the representation scale and to the environment in which it will be inserted to. The points of strength that link the procedure to the monuments the stone of the elephant represent are the natural shape, the human artefacts producing smooth parts in the stone carving, the impossible task to define a regular geometric pattern as real solution to the description of the monument; the real need to have a continuous variation of the level of details while changing the representation scale.

2.2.3 The Volcanic Rocks of Elephant Stone

On the geological front of the analysis for this monument the some meaningful sample collection is just completed and the geological research unit is working on the materials study. All the collected and treated information will be then linked to the pointcloud model to create specific visualizations of the decay conditions of this particular and unique stone.

The Elephant stone are pyroclastic rocks with welded from high- to medium-grade and a strong heterogeneity, due to variable presence of lithic fragments, lithoclast (with various size, until to decimetre) and pumice into the matrix of stone. These rocks have an open porosity ranging about from eight to 25% (in litho-clasts and lithic fragments of lava-like ignimbrites with strongly welded); the matrix of these pyroclastic rocks, characterized from low- to medium-welded grade, the open porosity varies about from 15% (into unaltered matrix) to 45% (in altered matrix). In some sample strongly altered, the porosity comes to 50%.

What happens inside the vitreous matrices, already characterized by poor welding original (Macciotta et al. 2001). Microscopic analysis indicated that the ignimbrite of Elephant stone have a porphyritic structure (with porphyritic index between 10÷15%) with phenocrysts of opaque minerals (magnetite and/or titanomagnetite), plagioclase, \pm clinopyroxene and rare quartz. Actually, further analyses are in progress.

2.3 The Mushroom Stone

About the Carloforte Mushroom Stone it is possible to say “we just arrive too late” a large part of the stone remembering the “umbrella” of the mushroom collapsed in March 2010, while a survey was planned for the end of may 2010. The mushroom is an ancient stone completely developed by the action of the atmospheric agents (e.g. wind with marine aerosol, meteoric water, thermoclastism, etc.; see paragraph 2.4 Decay of stone witnesses) over a very articulated volcanic stone.

A particular alteration process has produced a kind of “umbrella” over a more solid rock. The reasons of the fall are probably due to a natural issue, but this simply underlines how urgent is a survey of these fragile system. So, even if in its hardly damaged shape, the survey was done in June 2010.

The complex shape of this stone and the demanding walk needed to reach it with all the instruments, made us prefer to operate with a light phase-shift scanner like the Cam2 Faro Photon 80. The survey was based on spherical target system, to allow the reconstruction of each single scan into a unique model.

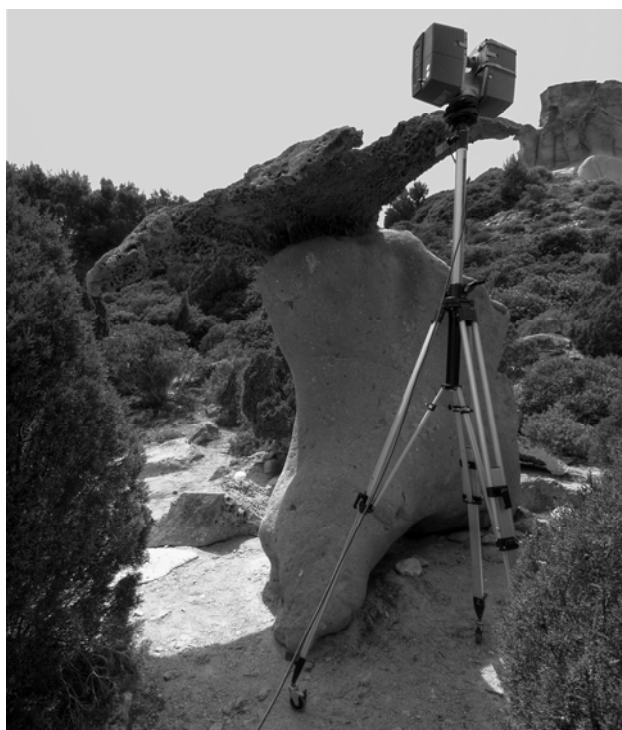


Fig. 4. The digital survey of the mushroom stone

The scans were taken in three series, a first series with the scanner placed directly on the ground, a second series with the scanner on the tripod at medium elevation and a third series with the scanner on the tripod at the maximum elevation.

In this way it was obtained a very good coverage of the whole stone and of the fallen fragment, mainly too large and heavy to try to turn them on the other side to try a scan of the opposite side, it was preferred to avoid this fearing to produce any further damage. A complete collection of sample and a first geological documentation of the whole stone and of the area around it was made.

A study about the various forms of macroscopic alterations was made on site with the gathering of small samples from monument stone.

All the digital survey data and all the geological data (physical, geochemical and petrographic characteristics of geomaterials) are now under development and analysis, in the next months it is planned to investigate what is effectively happened to cause the collapse of the umbrella and to define a clear picture of the state of decay of this stone.

2.4 Decay of Stone Witnesses

Aside from the late-stage syngenetic alteration processes, the pyroclastic rocks of Elephant and Mushroom stones are greatly affected by epigenetic alteration.

Decay processes are mainly concentrated in the vitreous matrix of pyroclastites, characterized by a higher porosity and low degree of welding, and carry on two different ways: (a) geochemical and mineralogical alteration and (b) physical degradation. In the first case (a), late-stage chemical alteration processes transformed partially the original paragenesis to a greater or lesser extent, altering the mineral assembly and the glass (with incipient devitrification) with the formation of new secondary minerals. In the second case (b), the mechanisms of physical degradation are principally related by: 1) presence of soluble salts (from soil or atmosphere) that exert a crystallization pressure into open porous of stone; 2) differential thermal dilatation induced by normal day range of temperature and solar radiation; 3) absorption/desorption in the stone of meteoric water (Columbu et al. 2008) or water from soil or air moisture; 4) water hydration/dehydration of hygroscopic mineral (e.g. salts). Nevertheless, the decay mechanisms of these two stone witnesses are different.

This depends, on the one hand, by different microclimatic conditions and exposure of stone surface to atmospheric agents and, on the other hand, by different physical and mineral-petrographic characteristic of geomaterials.

In fact, the Mushroom stone is located near to the sea (about 200 metres), while the Elephant stone is located about 3.3 kilometres from the sea. Moreover, the pyroclastic rocks of Elephant have different petrographic features and then are more heterogeneous, due to the greater presence of lithic fragments, lithoclast into the matrix. In the Elephant and Mushroom monuments there are diverse macroscopic forms of physical decay (decohesion, exfoliation, alveolation, differential degradation) and presence of crypto- and ef-florescence.

These macroscopic forms are distributed differently in them extern surface of each stone. In the Elephant the decay processes are mainly concentrated: 1) in the basal part of the big block of stone (that rests directly on the soil and is characterized by presence of circulating water solution by capillarity), with strong backward vertical profile of stone; in this zone differential degradation, with enucleation of lithic fragments and lithoclast, and exfoliation are the principal alteration macroscopic forms; 2) on the top and median parts of Elephant stone that exposure to the SE-S-SW-W and where there is more frequent the solar radiation; in these zones strong alveolation processes and physical degradation are more present, due to the differential thermal dilatation and diurnal cycles of moisture absorption/desorption; the alveolation is present mainly under the 'proboscis' of Elephant and into the outer room of 'domus de janas'. In the other outer parts of the monument with exposure to the NE-N, there are bio-deterioration agents (e.g. musk, lichens, etc.). In the Elephant stone, oxidation processes were observed. XRD analysis performed on the collected samples take on extern surface of parts of monument exposed to south and to west, indicated the presence of hematite, consequently to alteration of Fe-Mg minerals.

Diffraction analysis on other samples taken on the outer crust of precipitation indicated the considerable amounts of gypsum.

It is planned to investigate which is the origin of this phase; probably, it come partially from meteoric precipitations because these have often a small quantity of gypsum; this is formed by interaction of sulphur dioxide, acidic rainwater and atmospheric particles of CaCO_3 .

Inside the ‘domus de janas’ of Elephant stone, precipitation crust are present in surface of wall and ceiling of the small rooms. These crusts will be studied for determination the composition of secondary phases.



Fig. 5. Macroscopic alteration form of alveolation on the surface under the proboscis of Elephant stone of Sedini with the presence of salts within to the vitreous matrix of volcanic rock

In the Mushroom stone the decay (that produced a particular kind of “umbrella”) shows: 1) exfoliation in the stem of the mushroom; this alteration form is concentrated: a) where there are mechanisms of water wash-out, that remove constantly thin flakes produced by other alteration processes, b) on face of stem exposed to the north-wind come from the sea. The meteoric water run along the stem by fractures and fissures present into the top head of mushroom; on the base of first macroscopic

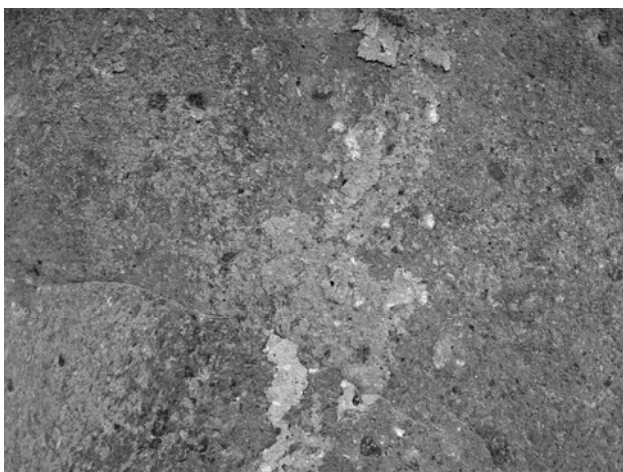


Fig. 6. Physical decay of stem of Mushroom stone of Carloforte with exfoliation processes by mechanisms of absorption/desorption and wash-out of meteoric water



Fig. 7. Macroscopic alteration form of alveolation under the head of Mushroom stone of Carloforte

observation, probably parts of head collapsed due to the presence of these fissures; 2) articulated alveolation (that penetrated until about 8 cm from surface below) under head where coexist two important factor of decay: a) physical decohesion of stone, therefore to continue mechanisms of absorption/desorption of meteoric water or humidity, containing a small quantities of seawater (with salt), (note: the thickness of head of mushroom is about maximum 30 cm), b) turbulence induced near to the mushroom by the sea-wind, which can frequently remove the thin flakes of stone weathered.

In the near future it is planned to investigate what is happened to cause of collapse of the “umbrella” (with determination of properties of resistance physical-mechanics of stone under stress of own lithostatic load) and to define actually state of decay of this natural stone monument.

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The geological survey of the elephant stone was made in 2010 and coordinated by Stefano Columbu. The research group is also composed by Prof. Giampaolo Macciotta, Prof. Marco Marchi, Dr.ssa Anna Maria Garau.

The survey of the Mushroom Stone was made in 2010 in collaboration with Area3D s.r.l. Livorno, the survey team was coordinated by Giorgio Verdiani and composed by Stefano Columbu, Alessandro Peruzzi, Filippo Fantini, and Gaia Lavoratti.

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3D Modelling of the A Famosa Fortress in Melaka, Malaysia

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Abstract. This paper presented our approach to developing the 3d model of A Famosa Faortress in Melaka, Malaysia. As the physical remnant of the fortress are minimal, a traditional 3D modelling technique based on collected data has been adopted. This method has been adopted based on case studies of three comparable reconstruction projects namely Michelsberg synagogue, The Jewish Quarter in Regensburg and Reconstruction of the old main church in Curitiba, Brazil. In this paper we discussed the 3D modeling technique used and presented some output of the model.

Keywords: Fortress, 3D model, A Famosa, conjectural layout, visual data.

1 Introduction

Historically, the A Famosa Fortress is one of the oldest partially extant European buildings in Malaysia. Its origins may be traced back to a fortress built by the Portuguese in 1511. The fortress is located in the city of Melaka and was largely destroyed during the British occupation of 1824 and the remains are currently as shown in Figure 1. Throughout the 300-year period of occupation it went through several architectural developments and changes. Recently Melaka has been listed in the UNESCO World Heritage list and Malaysian government have put significant resources into preserving this old heritage. A large amount of money has been allocated for excavation and conservation work as an effort to preserve this historical relic. Within the last few years, the conservation team has started to reconstruct some of the found areas. Most of these areas are locations for the bastions. However, work to uncover more of the buried wall, despite its historical significance and potential to draw more tourists into the area, may not be feasible as it would involve tearing up the major road that links the old town with the new commercial area, which has been reclaimed since the days of British occupation.

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Fig. 1. Remains of old Portuguese fortress, Porta de Santiago gate in Melaka

With the complex logistical condition and geographical factors of Melaka city today, it is undesirable to fully reconstruct this fortress in its physical context. Considering all these factors, it is believed that rebuilding the fortress in the form of a 3D model is the most practical solution. As the physical remains of the fortress is minimal, advanced 3D modelling techniques such as photogrammetry and 3D laser scanning are not applicable.

To identify the appropriate technique to be used, 3 projects which have similar situations has been selected and studied namely Michelsberg synagogue, The Jewish Quarter in Regensburg and Reconstruction of the old main church in Curitiba, Brazil. Table 1 compares the findings of these 3 projects with A Famosa. In general, the main similarities between this reconstruction of A Famosa and the three case studies are the very limited data resources and minimal physical remains of the building available. However in terms of available data, Lost Jewish Heritage and The Old Main Church of Curitiba have some advantages over the A Famosa and Jewish Quarter in Regensburg since the buildings were still available until the 19th century. Therefore, they provide more reliable evidence through photographs of the original buildings as compared to drawings or paintings. The architectural drawings produced in this era are also more accurate and advance compared to those of previous eras. In the case of A Famosa and the Jewish Quarter in Regensburg, extensive data verification has had to be done due to very old, inconsistent records and insufficiently reliable data.

Based on these findings it was decided to use a traditional 3D modelling techniques to reconstruct A Famosa. To accomplish this modelling process, 3D Studio Max has been chosen for the entire process of 3D visualisation such as polygonal modelling, texturing, lighting and rendering.

2 The 3D Modelling Process

Prior to the 3D modelling process, extensive data collection and verification has been conducted [4,5,6]. Once all the data has been verified, the 3D modelling process commences through several stages. First is the modelling of the fortress elements followed by the modelling of the fortress wall. Then the process is completed with texturing, lighting and rendering.

Table 1. Comparison of the elements in case studies

Project Elements	Lost Jewish Heritage [1]	Jewish Quarter in Regensburg [2]	The Old Main Church of Curitiba, Brazil [3]	A Famosa
Building's year	1869-1938	9 th century - 1519	1714-1875	1511-1807
Project's Year	1998	1998	2004	2007
Conservation	No	No	No	Partial
Who	University of Applied Sciences, Germany	University of Applied Sciences, Germany, research agencies and other institutions	Master thesis by Jose Manoel Kozan	Strathclyde University and Multimedia Univ.
Purpose	To preserve and reconstruct in digital medium (3D)	To preserve and reconstruct in digital medium (3D)	To preserve and reconstruct in digital medium (3D)	To preserve and reconstruct in digital medium (3D)
Available physical remains	No physical remains at all. The site has been converted into a highway	No physical remains except some foundations from the excavation	No physical remains except tower clock	Only a gate and some bastions from excavation data
Available data	Some old photographs and water colour drawings Historian records	Limited drawings and excavation data Copperplate engravings	Photos of the original building, old paintings, drawings and maps, similar buildings	Old report, inconsistent drawings with old measurement units, similar fortresses
Method	Traditional 3D modeling process based on available data No data verification involved	Traditional 3D modeling process based on available data Data analysis and interpretation done by curators	Single image photogrammetry based on tower clock and photos	Traditional 3D modeling process based on available data. Conducted extensive data verification process on available data
Output	3D computer animated film	3D presentation in video, CD and picture	3D model and rendered images	3D model and rendered images
Applications	Presented to public and won some awards for the film	Presented in the museum for public	Education and research purpose	Potential application for education and tourism in Malaysia

2.1 Modelling of the Fortress Elements

In this process, the A Famosa plan in Figure 2 is divided into several sections. For each section, three sketches were made presenting a perspective view, internal wall view and external wall view. The sketches have been drawn based on the findings which have been gathered using two approaches:

- 1) Defining the fortress elements through detailed study on the features of medieval fortress and fortress architecture
- 2) Matching the elements to the surviving fortresses from the Dutch and the Portuguese eras. This is done through site visits to three selected fortress which are:
 - Aguada fortress, Goa, India
 - Galle fortress, Sri Lanka
 - Rotterdam fortress, Indonesia

These sketches are then presented to three identified persons who have been the main figures in the excavation and reconstruction of Middelburgh bastion on site for evaluation and feedback. Based on the feedback received, any required modification and adjustment is made. This pre-visualisation process is very important before commencing with the 3D modelling stage. This is to ensure that only finalised elements of the fortress will be modelled in 3D model. Based on these sketches the modelling of fortress elements in 3D were done accordingly.

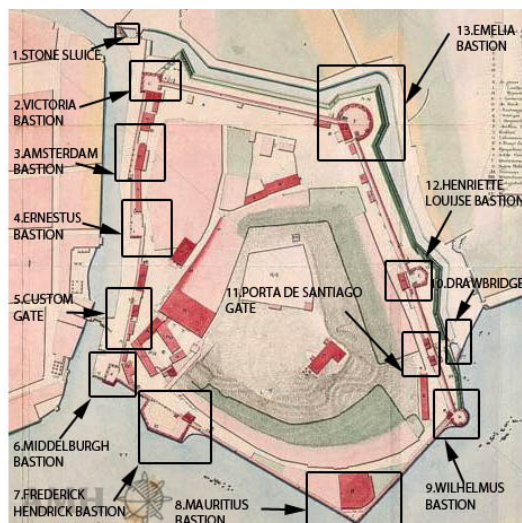


Fig. 2. Sections of the drawing transformed into sketches

2.2 Modelling of the Fortress Wall in 3D

To start the modelling of fortress wall process, the statistically-verified conjectural layout of A Famosa has been mapped onto the satellite image from Google Earth.

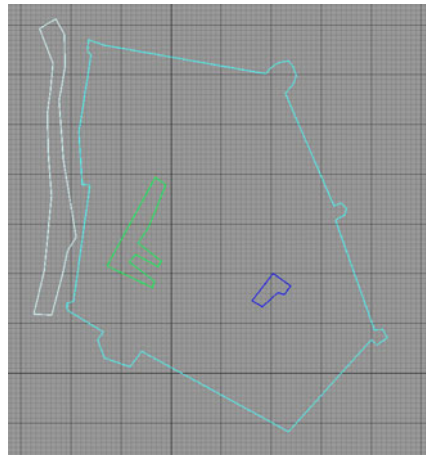


Fig. 3. Extracted line drawing of the conjectural layout of A Famosa

This is to match the location of the layout with the existing topology and mark the location of surviving buildings from the Portuguese and the Dutch era such as St. Paul's church and the Stadhuys. The information is then exported to a line drawing as shown in Figure 3 to be used in a 3D application.

Figure 3 has been used as the basis for the modelling process which started with the construction of the fortress site topology. This involves modelling the river, the seaside of the fortress and the land. After that the fortress line is extruded to become the wall and the 3D model of the fortress elements such as the bastion, gates, walls, ramps and passageways are then included. Since the fortress elements are modelled individually, any further detailed development and amendment can be done separately. Polygonal modelling has been fully used to model the entire 3D model.

To complete the 3D visualisation of this fortress, mock-up building models have been included inside the fortress. These buildings are not part of this research scope, and have been added for illustration purpose only. Figure 4 show the top of the 3D model of A Famosa.

2.3 Texturing

Once the modelling process is completed, textures are mapped onto polygonal surfaces. To control textures individually, each element is divided into several polygonal surfaces. Each polygonal surface has a specific texture. To avoid repetitive textures and to create a realistic look, textures have been created with various tones, patterns and styles. All of these textures were collected during the research fieldtrip to Sri Lanka and India. Manipulation of these textures is performed in Adobe Photoshop.

2.4 Lighting and Rendering

To create the finished 3D model, lighting and rendering must be applied. With the advancement of lighting and rendering technology today, photorealistic rendering

output can easily be achieved by using minimal 3D lighting. This method is known as physical based lighting. It mimics the real lighting based on the real world. To accomplish this, a rendering method known as Mental Ray has been used. It uses a global illumination approach to create a photorealistic output. Besides a realistic lighting output it also produces a very soft shadow. This combination has given a very promising result to projects that require a realistic rendering output. Final rendering outputs are based on the framing of the 3D camera. Generally these framings are positioned at the most significant locations such as the bastions, gates, walls and overall views of the fortress.

3 The Rendered Output

In this section we presented some rendered images of the significant elements of the fortress such as bastion, gate and wall.

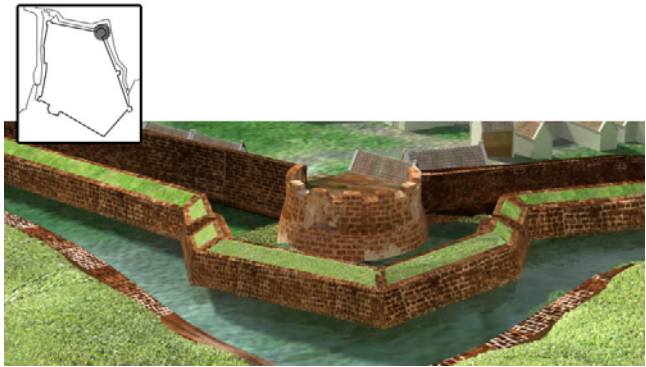


Fig. 5. Emelia bastion



Fig. 6. Frederick Hendrick bastion

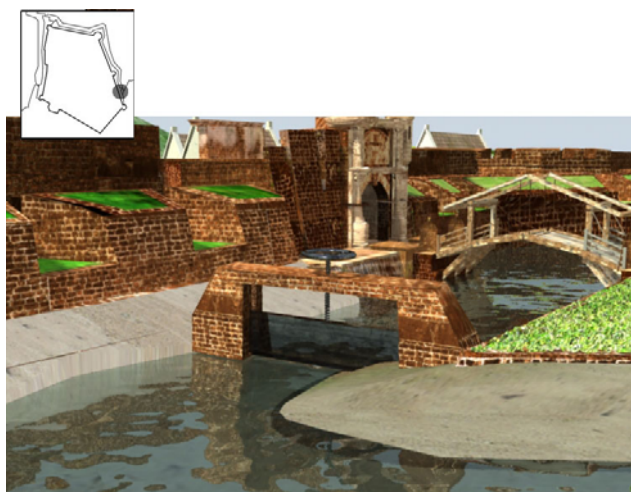


Fig. 7. Drawbridge at Porta de Santiago gate



Fig. 8. Overall look of the fortress from the sea

4 Conclusion

This project paper presented our attempt to model A Famosa fortress in 3D. Based on the comparison with some selected similar 3D reconstruction projects, it is decided to use traditional 3D modelling techniques using 3D Studio Max for the modelling of this fortress. Prior to the modelling process, extensive data collection and verification has been done to gather all the required data on the fortress since the physical remain of the fortress are very limited. The 3D modelling process commences through several stages which are the modelling of the fortress elements, the fortress wall, texturing, lighting and rendering. The output of this project are some rendered images of the important fortress elements such as the bastions, gates and walls. By modelling this fortress in 3D, we hope to digitally preserve this important heritage and search for possible application of the model in the education and tourism industry.

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3D Digitization and Its Applications in Cultural Heritage

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Abstract. 3D digitizing technology has a variety of applications including reverse engineering, quality control, virtual reality and digital heritage. Recently, great development in 3D digitizing technology facilitates archaeology and digital preservation of cultural heritage. In this paper, we introduce a 3D digitizing pipeline for cultural heritage. By using 3D technology, both geometry and texture can be recovered with high precision. Four main applications including digital archiving, 3D line drawing, virtual restoration and virtual display are introduced. The technology has been successfully implemented in many digital heritage projects such as Longmen, Xiangtangshan, Maijishan, Nanyuewang museum and so on. These projects demonstrate that 3D digitization greatly facilitates archeology and plays an important role in cultural heritage protection.

Keywords: 3D digitization, 3D scanning, 3D line drawing, Geometric modeling, Texture mapping, Cultural heritage.

1 Introduction

Digital heritage and archaeology have attracted a lot of attention of researchers in computer vision and computer graphics. A large number of cultural heritage objects are being destroyed due to natural weathering, eroding or disaster. Capturing digital representation of these heritage objects can be used for the preservation, restoration, access, and scholarly study. Recently, great development in 3D digital technology facilitates archaeology and digital preservation of cultural heritage. Representative examples include the Great Buddha Project [1], Stanford University's Michelangelo Project [2], Columbia University's French cathedral Project [3], etc.

China is an ancient civilization country with a long history and there are many world cultural heritage sites. During the past several years, we have carried out several digital heritage projects including some grottoes such as Longmen, Maijishan, Xiangtangshan, Huangzesi and some museums such as Nanyuewang Museum, Henan Museum, etc. The heritage objects were destroyed to some extent. It's urgent for us to protect the cultural heritage and preserve, study and display them using new technology.

By using 3D technology, both geometry and texture can be recovered with high precision. The 3D models can be used in digital archiving, 3D line drawing, virtual restoration and virtual display. To obtain the high precision 3D models, we use a global registration method based on feature points. We also design a 3D database management system to effectively manage 3D data, 2D photos and relevant texts for

different levels ranging from large scenes to a single statue. For 3D line drawing, we propose a multiscale approach to detecting the feature lines on the noisy meshes automatically. Different display methods are also proposed to display the cultural relics of different size.

2 3D Digitizing Pipeline

The pipeline of 3D digitization includes 3D data capturing, 3D registration, geometric modeling and texture mapping. For capturing 3D data, we can use different methods to obtain the range data from several views. Then the multi-view 3D raw data need to be registered and merged. The geometric modeling process includes polygonizing the point cloud, filling the holes, decimating the mesh and some other postprocessing procedures. The output of geometric modeling process is a mesh which can represent the geometric property of the object. For realistic rendering, texture mapping is needed to map high resolution photos onto the geometric models.

2.1 3D Scanning

There are several types of scanners available now in the market. For large scenes, time of flight scanners can be used to obtain the 3D data. Time of flight scanners can capture the 3D information of a large scene very fast. But as the measurement is based on finding the distance of a surface by timing the round-trip time of a pulse of light, so the accuracy is not so high, usually several millimeters. If high accuracy measurement is needed, structured light scanner based on triangulation is a good choice. Fig. 1(a) and Fig. 1(b) show the scanning of a cave using time-of-flight scanner HDS6000 and structured light scanner OKIO respectively. Fig. 1(c) and Fig. 1(d) show the comparison between a Buddha head scanned by the two scanners. We can see clearly that the details are well captured using structured light scanner.

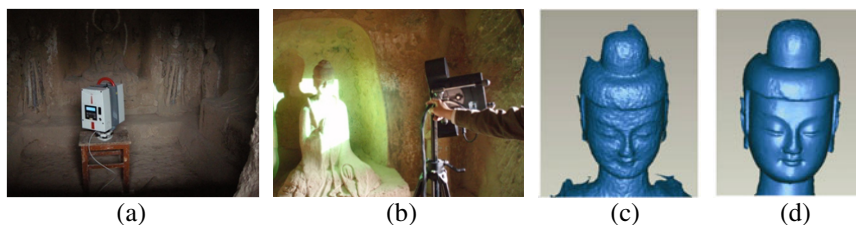


Fig. 1. 3D Scanning. (a) 3D scanning using a time of flight scanner. (b) 3D scanning using a structured light scanner. (c) Data scanned using a time of flight scanner. (d) Data scanned using a structured light scanner.

2.2 3D Data Registration

When we scan a large scene using structured light scanner, it may need several hundreds of scans to cover the entire surface. A serious problem for the registration of so many views is the accumulated error, such as the cave data shown in Fig. 2(a, b), where the red circle shows the accumulated error.

3D data registration is the process of aligning 3D data in different positions to one coordinate system using rigid transform [4, 5] or non-rigid transform [6]. One popular method of registration is to get a rough match among the data and use ICP [7] to refine the registration result. For multi-view registration, several methods have been proposed aiming at reducing the accumulated error [4].

In this paper, we use a practical method of multi-view registration using feature points based on the structured light scanner composed of two CCD cameras and one projector, which is memory and time efficient and easy to implement.

The global registration method includes the following steps:

- (1) Obtain the 3D coordinates of the feature points in each scan. The feature points can be man-made markers or image features such as SIFT feature.
- (2) Build the global frame for all the feature points.
- (3) Register each point cloud to the global frame, as shown in Fig. 2 (c).

The global frame for the feature points is the optimized coordinate for the points of each scan by considering error accumulation. The transformation matrix for the feature points to the frame can also be calculated. We use the same transformation matrix to transform the point cloud. By removing the overlapping data, we can get the point cloud as shown in Fig. 2(d, e). We can see that the registration error caused by the accumulation is eliminated.

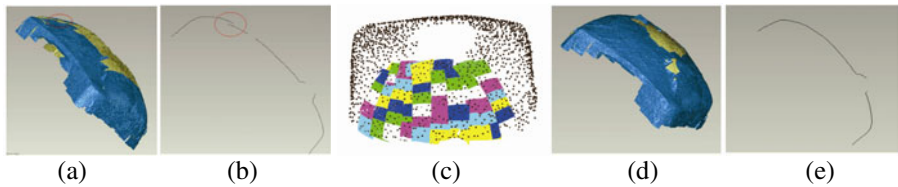


Fig. 2. Global registration method. (a) Error accumulation shown in 3D mesh. (b) Error accumulation shown in one cross section. (c) Registering each point cloud to the global frame. (d) Registration result shown in 3D mesh. (e) Registration result shown in one cross section.

2.3 Geometric Modeling

As the 3D data obtained by the 3D scanners are discrete 3D points without any neighbourhood relationship, meshes can be constructed from the point cloud by connecting neighbouring points to polygons. The polygon model can represent the object very well, which is much easier to be postprocessed and rendered than the point cloud. Several polygonization methods can be applied such as Marching Cubes [8], Delauney triangulation and so on.

With the rapid development of the 3D scanners, the 3D model can represent the object with high resolution and accuracy. Meanwhile, the data storage is increasing rapidly, which makes a big challenge for rendering, viewing and editing. Polygon decimation is the data reducing process that tries to use fewer polygons to represent the original object while preserving the features. Because of the complicated structure of the scene, occlusion or the special reflective property of the object, it's inevitable that the 3D data of some parts can not be captured and there will be holes on the model. The holes need to be filled to make the model watertight. Distance field based

method [9], method using symmetry, method using RBF and so on can be used to fill the holes of objects.

2.4 Texture Mapping

Texture is as important as geometry for realistic 3D digitizing. Texture mapping is the process to map high resolution photos onto the geometry model. Each vertex on the mesh not only has its 3D position but also has a texture coordinate corresponding to the texture image.

The steps of texture mapping are as follows:

- (1) Capture high resolution photos from multiple views under proper light conditions.
- (2) Segment the mesh into several parts.
- (3) Recover the projection relationship between each part of the 3D model and the photos to obtain the correspondence between the vertex on the 3D models and the pixels in the images.
- (4) Blend the color between the corresponding points on different photos.
- (5) Generate the texture images for different parts of the model.

3 Applications in Cultural Heritage

3.1 Digital Archiving

The 3D data of cultural heritage can be preserved permanently using the 3D digitizing technology described in the previous section. With the fast development of 3D scanning technology, multi-resolution 3D data of the objects in which we are interested can be captured. The geometry and texture can be recovered with high precision.

The heritage objects are of different type and size and the 3D models are of different resolution. Therefore, how to manage, search and display the information is a critical problem. We design a 3D database management system to handle 3D data, photos and relative texts. The database is based on Microsoft Access database. The features of the system are as follows:

- (1) Manage the data in multiple levels ranging from large scenes to a single statue.
- (2) 3D models, photos and texts can be included in the system and they can be switched to each other.
- (3) The user can view any details of the object freely.
- (4) Some analysis functions are also provided such as measuring and sectioning.

Fig. 3 shows the interface of the 3D database management system with 2D photos, 3D models and 3D measurement.

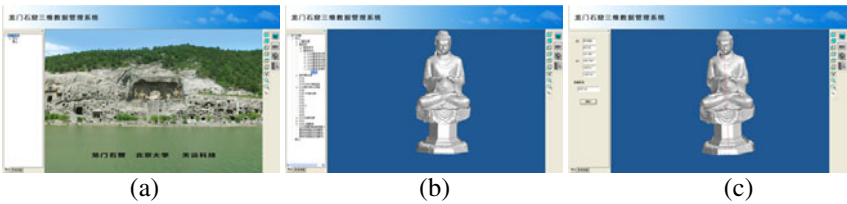


Fig. 3. 3D database management. (a) 2D photo. (b) 3D data. (c) 3D measurement.

3.2 3D Line Drawing

In archaeology, line drawings are essential components of archaeological reports [10], which depict the shapes and structures of heritage objects. Specifically, the measurements are recorded in the line drawings. Therefore, they can be utilized in archaeological illustration and restoration of heritage objects. Traditionally, the archaeological line drawings are made manually by archaeologists. However, the procedure is expensive and time consuming.

In order to generate 3D line drawing, we present a multi-scale approach, which can capture shape features at multiple scales and be robust to noise [11,12]. We construct the discrete 3D multi-scale representation based on random walks and select local scales with a probabilistic method based on the minimum description length (MDL) principle. Finally, the line drawing is generated by detecting ridges and valleys on the mesh model with selected scales.

Fig. 4(a) is a Buddha in LeiGutai in Longmen grottoes, which is about 1.8 meters wide and 3 meters high. The 3D model is shown in Fig. 4(b). The distribution of local scales is illustrated in Fig. 4(c), which is piecewise constant and discontinuity adaptive. Combining curvature information with selected scales, the ridges are traced by connecting the zero-crossing points of first-order derivatives of maximal principal curvatures. Compared with the manual drawing in Fig. 4 (d), the 3D line drawing in Fig. 4(e) captures the main shape of the Buddha.

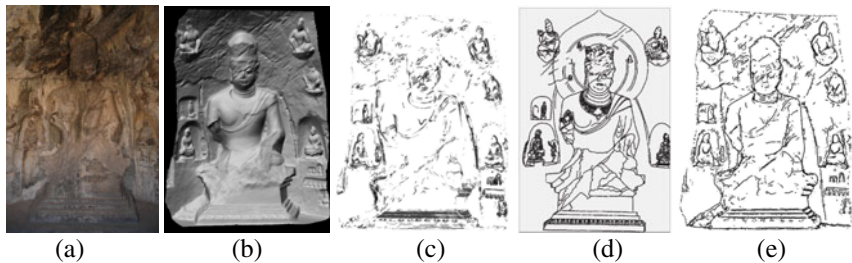


Fig. 4. 3D line drawing for a Buddha in Longmen grottoes. (a) Photo of the Buddha. (b) 3D model. (c) Local scales. (d) Manual drawing. (e) Multi-scale ridge detection.

3.3 Virtual Restoration

In China, many cultural relics are broken or stolen, so restoration is a very important part of protection and study of cultural relics. Compared with the restoration on real objects, there is no damage to the cultural relics by virtual restoration and different restoration strategies can be applied to obtain a reasonable repairing result.

For different types of missing parts, digital restoration can be classified into the following categories:

(1) The missing parts can be found. The body and the missing parts can be scanned respectively and be merged together virtually. Several such projects in Longmen grottoes and Xiangtangshan grottoes have been carried out. In Longmen grottoes, two Buddha heads were back to China in 2005 and the archeologists found the bodies in the caves. Using 3D digitizing technology, we merge the missing parts with the body.

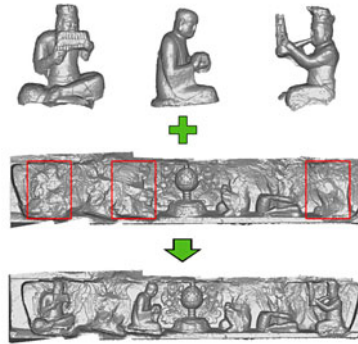


Fig. 5. Virtual merging of sculptures with the body from Xiangtangshan cave

In Xiangtangshan grottoes project, the archeologists from Chicago University scanned over twenty heads, hands or other parts outside China and the cave was scanned in China. The missing objects and the bodies are merged virtually. Fig. 5 shows the merging results of some sculptures with the body from Xiangtangshan cave. Fig. 6(a) shows the merging results of a Buddha head with the body from Huodingdong cave in Longmen grottoes.

(2) The missing parts are not found but can be inferred from the existing parts. The missing parts can be reconstructed based on the neighbourhood information. Fig. 6(b) shows the statue before repairing, and the repaired results based on the neighbourhood are shown in Fig. 6(c). From the general knowledge, we can see that the necklace should be a complete one and the bead should be similar and the curve on the clothes should be smooth. Based on these knowledge, the original appearance of the Bodhi-sattva can be restored.

(3) The missing parts are large. If there are old photos or any historic record, the restoration can be performed based on these evidence and the 3D models can be constructed manually. If there is no supporting material for the restoration, the restoration can be based on the statues of the same period but sometimes the restoration results will be very controversial.

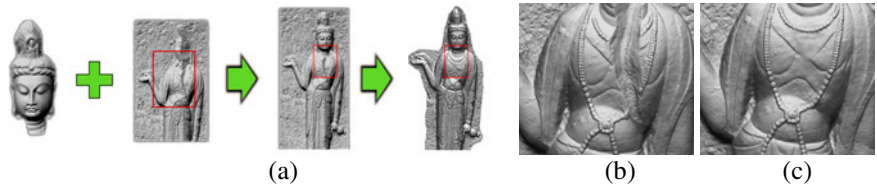


Fig. 6. Virtual restoration. (a) Restoration pipeline. (b,c) Enlarged view of the part before and after repairing.

3.4 Virtual Display

We know that there is a conflict between the cultural heritage protection and display. For example, when a visitor goes to a cave, usually he can only see the sculptures

outside the cave with several meters away from the statues to avoid any damage to the sculptures. Thus, the information that he can obtain is very limited. Virtual display can effectively solve this problem. The audience can enjoy the digital model from any viewpoint without any damage to the cultural relics.

For different scenes, different display strategies should be used. We design a virtual roaming system for large scene in which the user can roam in the scene and view any details of the scene. A stereo display system, consisting of a high frequency projector, stereo glasses and an infrared emitter, is also constructed so that the audience can be fully immersed into the 3D scene. Fig. 7(a, b) show some of the rendered scenes of Longmen grottoes. For small objects, an interactive viewing system is designed so that the viewer can rotate, move or zoom the object to any position and see the details. Fig. 7(c, d) show the interactive display of small cultural relics in the museum.

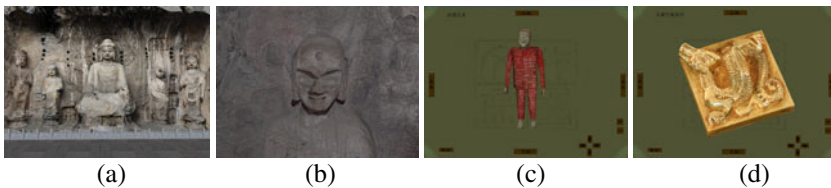


Fig. 7. Virtual display of heritage scenes. (a, b) Display of large scenes. (c, d) Display of small objects in the museum.

4 Conclusions

In this paper, we present a 3D digitizing pipeline for cultural heritage. The pipeline includes 3D scanning, 3D registration, geometric modeling and texture mapping. Different kinds of scanners can be used to obtain the 3D point cloud. For high quality scanning, we use an automatic global registration algorithm based on the registration of feature points. The global registration method is time and memory efficient. The resulting 3D model is of high precision with enough details. Based on the 3D model, we introduce the geometric modeling and texture mapping methods.

3D digitization has many applications in archeology and cultural heritage protection. Four main applications are introduced in this paper, which include digital archiving, 3D line drawing, virtual restoration and virtual display. The technology has been successfully implemented in many digital heritage projects. These projects show that 3D digitization greatly facilitates archeology and plays an important role in cultural heritage protection.

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Interactive Itinerary of Heritage Houses in Beirut: Walking Back to the Future

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Abstract. The aim of this project paper is to explore the opportunities and challenges of using ICT in the understanding, representation, preservation, management, interpretation of cultural heritage and its Man initiated deconstruction. Aggressive urban development and the rampant growth of tourism pose major problems to world heritage sites. Of particular interest for this project paper are issues related to the specific town of Beirut through interactive virtual reality, and making virtual reality user-friendly and available resources for the general public. A virtual Platform is presented in order to explore and map the challenges and opportunities of using ICT in cultural heritage. This virtual Platform provides a forum to examine and discuss current practices and future directions in the representation, documentation and communication of cultural heritage using ICT. It aims to provide an occasion to share and exchange experiences and research findings, to stimulate more ideas and useful insights regarding the uses of ICT in cultural heritage.

Keywords: ICT, web, interactive virtual reality, Beirut.

1 Introduction

This research project deals with the use of information and communication technologies (ICT) in the enhancement of historical cities, particularly in the case of the city of Beirut in Lebanon. Located in Lebanon, Beirut is at a crossroads between the Orient and the Occident. Beirut is at the centre of an amalgamation of cultures, which shows unique architectural land-marks boasting a number of lively ancient neighbourhoods. Beirut's history goes back more than 5000 years. Excavations in Beirut have unearthed layers of Phoenician, Hellenistic, Roman, Byzantine, Arab, Crusader and Ottoman remains.

The idea for this research arose from the study of certain ancient cities, of which sometimes only few old spaces remain, but that are important enough to merit further exploration: these spaces represent an architectural heritage. There are multiple definitions of heritage, and this a subject of ongoing debate among the various disciplines involved in its conservation. In our case, we define it as the know-how arising from the construction methods and ways of life that characterize a place through history. The goal is to reconstruct the “memory” of a place through the use of new

information and communication technologies (ICT). Heritage is a constantly evolving concept, particularly since 1989 when UNESCO introduced the notion of intangible heritage, the importance of which was confirmed by the “Convention for the Safeguarding of the Intangible Cultural Heritage” of 2003. The concept of intangible heritage is increasingly gaining currency. According to M. Petzet [12], “The preoccupation with what we try to de-fine as intangible heritage may also contribute to a broader emotional basis of conservation practice, which can help us in the daily fight against the progressive world-wide destruction and decay of our cultural heritage.” [12] Intangible heritage is not a static value, but an evolutionary concept: “The notion of intangible heritage must not be fixed at a particular point in time – it is dynamic and evolves and it is the evolving intangible heritage which is important.” [2]

It is also important to note that the concept of heritage was brought to Lebanon in the 19th century by European missionaries, explorers, archaeologists and other scientists interested in identifying and describing monuments from Antiquity and the Middle Ages in the Mediterranean. Since then, the notion of heritage in Lebanon has evolved and now refers to a specifically Lebanese heritage, with ideological undertones directly linked to national identity. Lebanon is composed of several social and denominational identities, which means that heritage is perceived differently according to one’s background. Without belabouring these nuances, suffice it to say that heritage and its preservation is a major issue in the world today, and is beginning to gain importance in Lebanon.

These new approaches to tangible and intangible heritage have guided our experimentation in developing new digital devices to protect and promote the architectural heritage through ICT. Beirut is loosing its heritage assets and its traditional houses (Figure 1) to make way for monumental concrete and glass buildings that rise up to the clouds. Old houses representing the culture, history and memories of many generations are being destroyed.

In a paper published recently presenting this research project [4] and understand why these buildings aren’t protected since they are officially classified as historic monuments we explained that the only existing law for the protection of architectural heritage dates back to 1933. In fact according to Article 1 of decree 166 issued in 1933 on old buildings: “what are considered as ancient remains are all things made by human hands before the year 1700 (...)”. The second paragraph of the same article states as follows: “(these buildings) are considered similar to ancient ruins and are subject to the rules of this resolution” (and therefore benefit from legal protection due to their classification). This also applies to all immovable things built after the year 1700 having historical and artistic value that respond to conservation needs and support the common well-being of the people. This law mainly protects buildings dating before 1700, although newer buildings may also be added to the list by the government.

In 1993, the High Planning Council appealed to a group of architects who had analyzed a number of ancient buildings and had established a list of buildings to be protected. At that time, 1 016 buildings were listed. In 1997, the list was reduced to only 520 buildings, representing only 2.5% of all buildings in Beirut. In 1999, the number decreased to 220. Mona Hallak, who sits on the board of the Association for the Protection of Ancient Sites and Residences (AP-SAD), argues that the list has only aggravated the situation by classifying buildings A through to E according to their state.



Fig. 1. Examples of threatened ancient neighbourhoods in Beirut

"A means that the house is in good condition whereas E means that it is in very bad shape," she says. This list implies that only the dwellings classified as A, B or C should be protected, while the others are left to demolition.

In 2007, Tarek Mitri, Minister of Culture at the time, proposed a law encouraging owners of old houses to maintain them through financial aid. The Council of Ministers adopted the law, however citizens are still waiting for the law to be ratified by Parliament. On April 12, 2010, the Cabinet adopted a decision to stop the demolition of heritage buildings in Beirut classified as A, B and C according to the consultancy study completed in July 1998 by "Khatib and Alami".

Promoters as well as owners suffer from a lack of financial resources with regards to heritage conservation. Both owners and developers want to make profits while saying they contribute to the growth of the country. However old buildings are in bad shape and threatened, and a lot of them have already been demolished. What one should be asking is whether the tourists will come to Beirut to visit the towers of concrete and skyscrapers. The disappearance of old homes in Beirut represents both an economic and cultural loss, a part of the history and culture of a country which is disappearing. [10] [13]

The city of Beirut characterized by threatened heritage is therefore relevant, and these issues encourages one to think about ways to contribute to the preservation of the heritage value of old sites while rampant urbanization continues." [4] (Figure 2)



Fig. 2. Examples of rampant development (photo workshop Gemmayzé, 2005-2007- ALBA)

2 Methodology

In the case of this research project, it is a question of developing a knowledge-sharing space whilst referring to the use of ICTs (Information and communication technologies) and the main objective has been to gain an understanding of heritage in order to demonstrate how, using new methods of representation, management and reuse of content and knowledge, we can attempt to virtually represent the tangible and the intangible: what is and what used to be. ICTs allow for an exploration involving the simultaneous use of simulation and experimentation, while respecting the guidelines set forth in UNESCO's charters on the safeguarding of heritage. [4]

With regard to techniques of representation, it should be noted that in the twentieth century architectural heritage was illustrated by means of drawings, plans, cross-sections and elevations produced by architects and archaeologists. Three-dimensional reconstructions of spaces were often created as well. Graphic reconstitution in the form of drawings is still widely used today for the enhancement of archaeological heritage. [3]

"The restoration of ancient monuments is another way in which architectural heritage can be enhanced. Restoration, according to Pérouse de Montclos, involves a number of different areas. These include "consolidation", which is done to ensure a building's durability, without modifying it; "reassembly", the reconstruction of a building whose parts are still available on-site; "re-constitution", the collection and reassembly of authentic elements that have been dispersed; and "repair", the replacement of deteriorated parts with new, identical elements. The physical reconstitution of monuments is now regulated. The Venice Charter, which preceded the one adopted in Victoria Falls in 2003, states "that architectural heritage must be considered within the cultural context to which it belongs, that conservation and restoration of architectural heritage re-quires a multidisciplinary approach, and that the latter is not an end in itself but a means to an end, which is the building as a whole." [4]

Finally, it should be recalled that, as with life-size reconstructions, scale models also are potential tools for enhancing architectural heritage. They can be used to depict a building, but of-ten provide no information on the factors related to its construction

history. Such models are limited to three-dimensional reconstitution of forms that are, in certain cases, hypothetical. They are often used as teaching aids, and also as tools to inform and entertain cultural tourists. ICTs can contribute as unifying elements in a collaborative and multidisciplinary environment. [7]

In our previous research we noted that “more than ever heritage is a subject of international concern and it would be appropriate to create collaborative spaces where one could share knowledge relating to threatened or even missing heritage; this collaborative workspace is an inter-connected environment in which all the participants can access and interact with each other. However the context of heritage is very broad: its concepts are difficult to define, particularly with the complexity of the themes considered. It will therefore be necessary to restrict the field of study to a specific example which is representative of heritage at risk, in other words, the selection of a case study. The example of Beirut in Lebanon is relevant because some neighbourhoods having historic character are disappearing in favour of rampant urbanization. In these neighbourhoods, we do not have many traces left, however, a study of the urban plan of Beirut is underway at the Lebanese Academy of Fine Arts (ALBA) as part of research activities related to heritage based on multiple data. It is therefore appropriate to develop as a first step documentation methods in order to later integrate information concerning heritage at risk in a knowledge sharing space accessible from anywhere via the Web. On the basis of our research data, we propose an initial digital space. This digital space allows the user to clearly identify cultural heritage spaces at risk in Beirut. Subsequently, a final interface is proposed which would meet the designer's target requirements more adequately. The project would be published on the Internet and its promotion of threatened heritage will raise awareness among different stakeholders. An important outcome of the research is to show that the threat of heritage loss is common to many countries where there are often cases of economic development at the expense of heritage conservation.” [4]

Based on the presented approach above, experiments have been developed and performed within the context of heritage preservation which deal with the protection and preservation of a building whilst considering its heritage value, using the new information and communication technologies (ICT) currently available. The results of our recent research shows that the roles of these new technologies are not limited to simple communication and representational tools. Increasing amounts of research have shown that they are also used as information tools to understand values, thereby allowing the users to take into account a number of different factors during the demolition of heritage buildings and traditional houses. Therefore the research work attempts to demonstrate that the appropriation of the heritage value of a heritage space is possible and can lead to its preservation. [4] [5]

3 Experimentation

During the presentation of this project at the 2nd International Conference on Heritage and Sustainable development (Evora, Portugal, June 2010) we said that “Today, many strategies are developed in favour of sustainable development. “The Brundtland report entitled *Our Common Future*, published in 1987, put forward the idea that “sustainable development answers to the needs of the present without compromising the ability of future generations to answer to their own”. Five years later the EU

Commission improved this formulation by stating that sustainable development was “both a policy and a strategy to ensure continuity of economic and social development while respecting the environment and without compromising the natural resources indispensable to human activity”. [6] In nearly each of our actions, we need to systematically take account of environmental aspects. There are also environmental challenges arising from the themes of the present article which should hopefully contribute to the preservation and protection of environmental and heritage issues. [14]

It is important to remark that, as outlined, in Heritage2010 program: “Nowadays, sustainable development was brought much forward than the concept expressed in the book “Our Common Future”, commonly known as “The Brundtland Report”. The role of culture and social aspects enlarged the initial statement where environment and economics took the main role, guiding the earliest research on sustainable development.” [16]

Efforts are currently being deployed around the world to preserve the spirit of places through the safeguarding of tangible and intangible heritage, which is regarded as an innovative and efficient way to ensure sustainable and social development throughout the world. [9] [11] Urban development is, among other issues, inducing transformations and creating disruptions within societies and there is a need to more fully understand these threats so as to prepare preventative measures and sustainable solutions. Developing ways of preventing degradation and destruction of heritage buildings is an urgent matter. Using ICTs for communicating and preserving such a heritage could contribute to the safeguarding of the spirit of place and better protect them from the threats of a changing world. [5]

In order to test models that could play a role in communicating places that represent examples of heritage in danger, we selected the city of Beirut, which includes streets characterized by heritage buildings. As a first step, we organized and described approaches for the transfer of knowledge (Figure 3) that allowed us to exploit representations of spaces with the help of digital modelling software. We then developed the information structure necessary to validate strategies for defining an informative representation interface, using software applications that enabled us to create web-based interactive digital devices. Starting with the modelling of the street, we tried to identify buildings within this space by including text data and images. This itinerary proposes web content where the user can interact with the proposed interface and find out in real time where the threatened places are located depending on the action selected. This interface can display the various layers and forms of a place so as to allow the user to learn through interaction with the digital modelling systems and by experiencing friendly interfaces. [15] Our method aims to provide new architectural solutions using technological means, with an emphasis on information gathered on heritage sites at risk. By using this approach, we hope to present a cognitive and interactive device, which enables the users to identify the heritage at risk. This system has the advantage of providing information on the site's location, its shape and future threats in order to stimulate action leading to its protection.

On the basis of our research results, we propose an initial digital model. This model allows the user to clearly identify cultural heritage sites at risk. Subsequently, a final computer model is proposed which would meet the designer's target requirements more adequately. This computer model attempts to simulate a model of a particular heritage site. (Figure 4).

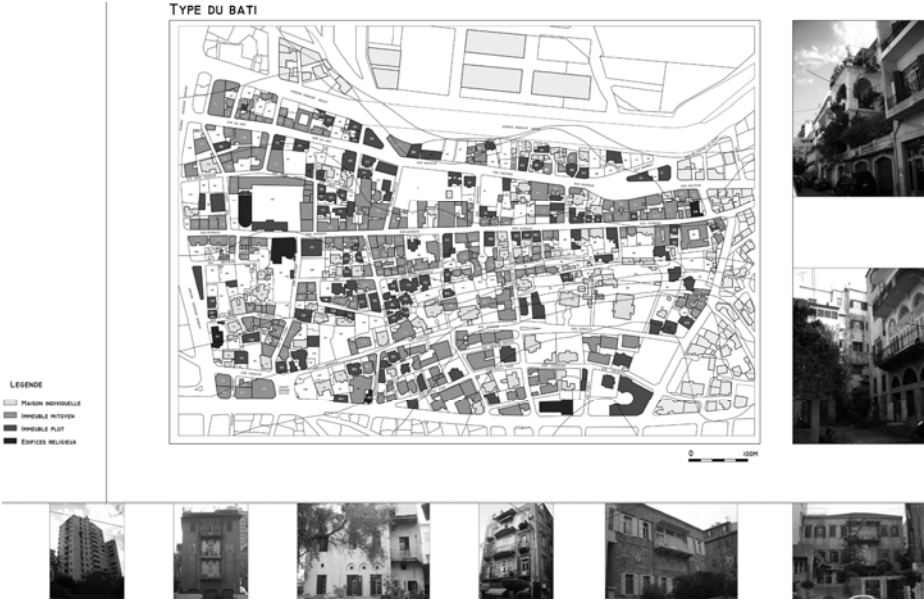


Fig. 3. Gathering data on buildings in Beirut. (workshop Gemmayzé, 2005-2007- ALBA)

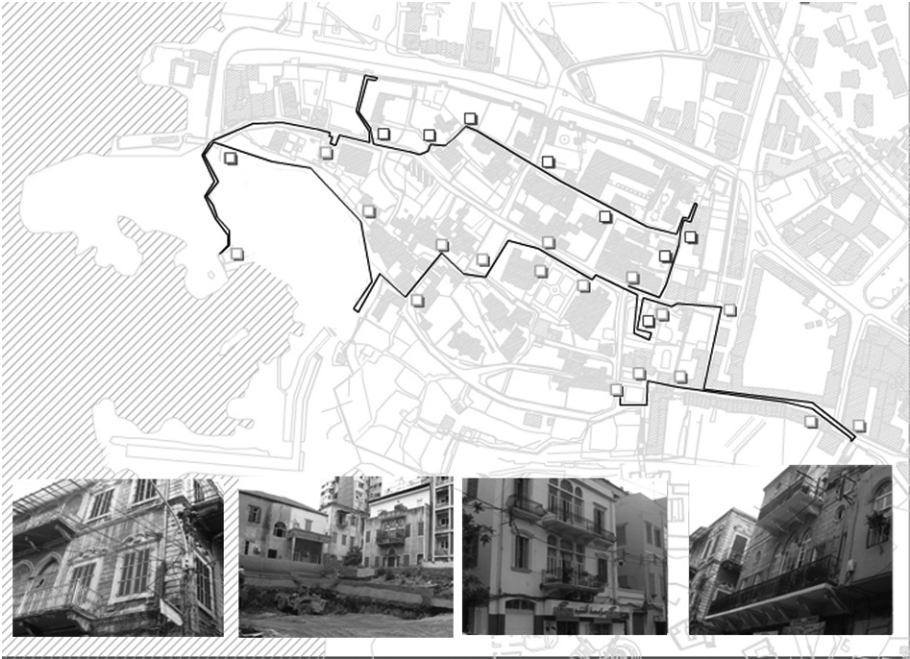


Fig. 4. Itinerary tracing heritage at risk

The results we propose lead us to believe that we can rely on computer tools to communicate heritage spaces at risk. Subsequent research contributes to the development of digital devices that can enable the communication of these heritage sites and contributes to the development of digital knowledge tools. In addition to the potential of simulation, virtual space opens new possibilities of expression and experience. It also helps to re-create and remould a monumental complex without having all the information and to test hypotheses that we would otherwise be unable to validate without compromising the heritage values of a site by physically reconstructing it. This was the case of Beirut, which we used as a case study.

4 Conclusion

This conclusion reiterates the remarks already made when presenting the project at the 2nd International Conference on Heritage and Sustainable Development [16], and following the recommendations of experts who point out that will be important to create a virtual-collaborative platform to enable effective exchange between project participants. In fact as we noted in our previous article “Over the last few years, a remarkable increase has occurred in the use of Information and Communication Technology (ICT) for the e-Documentation of the Past, how to preserve and manage Cultural Heritage, whether books, drawings, architectural and archaeological and discuss future methodologies and plans for the local and global cooperation in this area. This has drastically transformed the way we create, reuse and manage knowledge. Visualisation techniques, computer animations for Cultural heritage applications employed have evolved from standard surveying and CAD tools into interactive environments, laser scanning, virtual reality and fully automated video-based techniques. It is often heard that Virtual heritage tend to pre-sent value-free content and thus are inefficient in suggesting cultural and symbolic meanings. Virtual Heritage, as any other expression, tend to preserve, document, manage, present/visualise and disseminate the rich and diverse Cultural Heritage of Mankind. Thus the issue of using (ICT) for cultural heritage is by no means a simple one and must be considered from different angles.

More than ever before, the subject of heritage is of international interest. It would therefore be relevant to create collaborative spaces to unify diverse knowledge on threatened or extinct heritage. However the heritage field is extensive and complex: its notions are difficult to define and at times, to understand, thereby questioning the ambitions of the work proposed. The example of Beirut (Lebanon) a city characterized by threatened heritage, is pertinent as some of its neighbourhoods having heritage value are in the process of disappearing due to rampant urbanization, leaving little trace of their former character. Therefore it is important to establish documentation methods relevant to these disappearing traces, which can be integrated into these pro-posed knowledge-sharing spaces accessible on the Web. Through the development of an environment based on communication, this research project can be implemented in many countries, such as Canada, where certain heritage sites are in peril and many have already disappeared.

Furthermore, by putting the project on the Web, it allows for different players implicated in heritage and in particular, threatened heritage, to better understand the issues relevant to this field. One of the primary benefits of this research project is to make clear that the threat of losing heritage is common to many countries where economic development is prioritized over heritage conservation. Future possible work which furthers the work proposed in this paper involves developing a portrait of different world heritage sites in peril so as to allow those concerned with the future of these sites to communicate the information they have garnered through this knowledge-sharing space and propose solutions for the site's conservation so as to best protect it.

This research work tries to offer an opportunity to raise public awareness concerning the diversity of Lebanon's heritage and the efforts that are required to protect and conserve it, as well as to draw attention to its vulnerability. The proposed work is essentially an exchange between people and established results, where the increased use of ICT offers a renewed use of the Web that improves information management and proposes a system of knowledge management. Let us consider the value of heritage buildings and houses in our lives and join in the effort to protect those sites which are threatened by neglect, destruction and degradation. In a small way, this research work is a contribution to this consideration." [4]

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Cultural Heritage and Sustainable Valorization in the Governorate of Tartous with Reference to the Euromed IV Project: The Contribution of Geomatics

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Abstract. Six Mediterranean countries are participating in the “Mare Nostrum” project: “A Heritage Trail along the Phoenician maritime routes and through the historic port cities”; the goal of this project is to valorize the cultural heritage of the sites involved by promoting and supporting sustainable tourism. WP4 concentrates on the port cities of Tyre and Tartous, chosen as pilot sites. The on site research was conducted in accordance with the WP4 objectives: on the one hand a survey campaign was set up to acquire metric and qualitative data on the structures chosen as samples; on the other hand an enormous amount of photographic and video documentation was collected for the 3D models that were produced in the first phase. The paper will describe how the disciplines involved in Geomatics can provide important contributions to all four phases of the Heritage and Development framework.

Keywords: Cultural Heritage, Laser scanning, Virtual Tour, Cultural Mapping.

1 Cultural Heritage and Sustainable Valorization

Six Mediterranean countries (Syria, Lebanon, Greece, Italy, Malta and Tunis) are participating in the “Mare Nostrum” project: “A Heritage Trail along the Phoenician maritime routes and through the historic port cities”; the goal of this project is to valorize the cultural heritage of the sites involved by promoting and supporting sustainable tourism.

This goal is being achieved by: raising public awareness of the importance of preserving and promoting sites; valorizing and promoting the Cultural Heritage of the different Mediterranean basin cultures in a more communicative way; promoting effective management plans to reduce the marginalization of archaeological sites and to enhance the centuries-old port-city relationship; defining management plans for target sites that will promote sustainable tourism.

WP4 concentrates on Syria and Lebanon where the port cities of Tyre and Tartous (including the nearby Arwad Island which is already on the World Heritage Tentative List) have been chosen as pilot sites. In both cities WP4 has to: identify

archaeological/urban sites and proposed re-qualification projects that will enable these sites to be better used; design two kinds of itineraries in a sort of “cultural map”: an urban map that includes the waterfront/city connection and a Mediterranean map that connects all the port cities involved in the project; place explanatory panels on site to provide information for tourists.

The concept of sustainability has a double meaning when it is applied to cultural heritage management: in the physical sense it means that excessive concentrations of tourists have to be avoided to ensure that the conservation of the cultural heritage is not compromised; in the economic sense it means limiting the cost-benefits differential and thus increasing the capacity for promoting development. Conservation management planning and the model for sustainable valorization can be integrated to evolve a new model wherein heritage serves as the core of the development process. This process moves through four phases: *Awareness*- Development begins with the identification of resources which have to be documented and studied to harness their potential use; *Appreciation*- Development emphasizes public participation in cultural heritage activities; *Protection*- The tools of reference are heritage charters (concepts, policies and practices) and conservation guidelines (technical standards); *Utilization*.

2 The Contribution of Geomatics

The contribution of geomatics does not only consist in the application of the latest information technology procedures but creates a new methodological behavior within the data acquisition and management process. Geomatic techniques can play a central role because they provide innovative and more complete ways of describing reality which, in their turn, allow approaches at different levels:

1. Geomatic techniques can manage enormous quantities of data relating to a single geographic location but generated at different times;
2. Extra features can be added to the representation field during the research phase using processing to reconstruct modifications that have taken place over time;
3. Georeferencing of data makes possible to link the existing relationship between cultural heritage objects;
4. The knowledge acquired can be widely disseminated on-line;
5. The information can also be transferred to external databases and web sites.

To sum up, the research for this project uses geomatic techniques to propose innovative ways of using case studies, allowing diverse analogous elements (the port cities linked to each other in the Phoenician commercial maritime routes system) to be considered simultaneously. In this sense it is possible to propose hypotheses for valorizing these heritage objects which take into account a series of conditions such as accessibility, current transformations within the area, relations between the more important monuments which profoundly effect their use. The use of these heritage objects should be seen as an opportunity for increasing our understanding of them.

The disciplines involved in Geomatics provide important contributions to all four phases of the Heritage and Development framework: awareness, appreciation, protection and utilization.

On the one hand the acquisition and manipulation of data for studying and conserving sites: preparing geometric and thematic surveys, setting up maintenance programmes and simulating models for predicting the impact of the tourist flow. On the other a powerful tool for communication. To provide the cultural heritage with such a powerful system for learning, enriched by information technologies, is certainly a first step towards a better understanding of the sites and an essential step towards their appropriate valorization.

3 Description of the Places

Tartous was founded in the 2nd millenium B.C. as a coastal settlement on land belonging to Aradus (the present day Arwad), a small island 3 km away and one of the most important Phoenician city-states. It expanded as an independent city under the Emperor Constantine and his son Costanzo II. The city was conquered by Arabs in 636 and was of little importance until it was taken by Raymond de San Gilles during the First Crusade. In the second quarter of the 12th Century the Cathedral of Our Lady of Tortosa, one of the best preserved Crusader religious buildings, was built. Its fortified structure makes it unique among the Latin churches of the Near East.

In 1152 Tartous became one of the main settlements of the Knights Templar who built the Citadel in the north-west corner of the city. This Citadel was built with double concentric walls and a double moat. Although dwellings were later built within

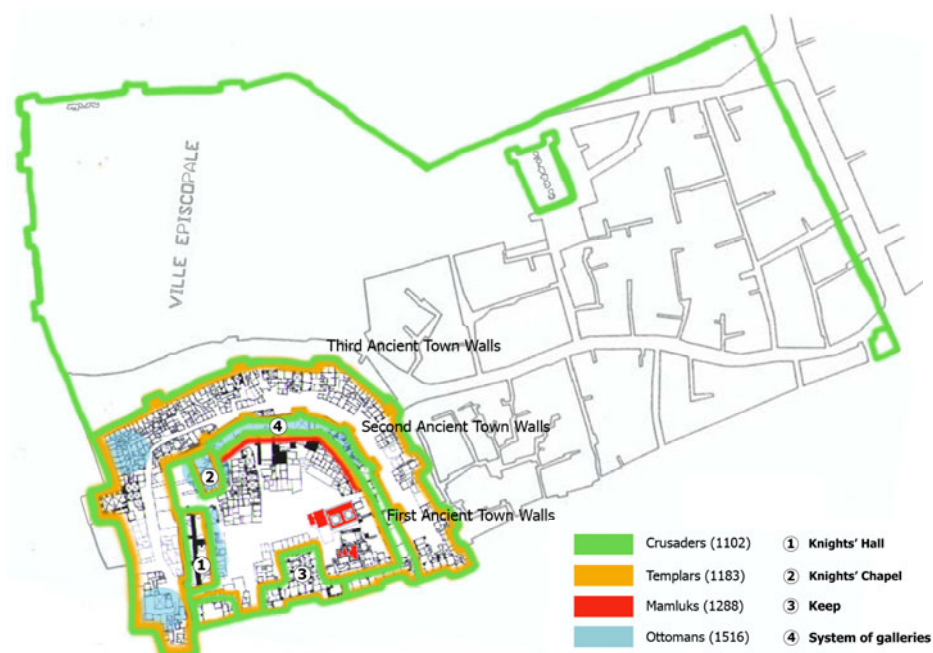


Fig. 1. Historical phases of the Citadel of Tartous. The numbers indicate the most important examples of Crusader architecture that are still recognizable.

the Citadel the remains of its walls and the most important Knights Templar buildings (the Keep, the Banqueting Hall and the Chapel) and the later Ottoman additions such as the galleries along the walls, are still clearly visible (Figure 1).

Tartous is currently the second most important city on the Syrian coast and is the main centre of a network of important points of interest for culture and tourism. The relationship with Arwad has now been reversed: the island is only a small town that depends mainly on local daily tourism. There are significant remains of the Phoenician Aradus on the island including the imposing remains of the walls facing the sea. The importance of Arwad during the Crusades is testified by the presence of two castles, one built by the Crusaders on the highest point of the island, the other built by the Arabs by the sea.

There are other important archaeological remains 7 km from Tartous at Amrit. The temple known as Maabed, is a basin carved into the rock surrounded by blocks of stone with an altar in the centre, which holds water from a nearby spring. Nearby there is a necropolis with underground tombs and two monuments called Meghazil.

There are also the remains of the docks of a port and a stadium from the Hellenistic period. Further from Tartous there are other important sites of cultural interest. One of the most interesting is the Hosn Suleiman archaeological area (the ancient Baeto-cece), a sanctuary dating from Phoenician times with a well preserved sacred enclosure and the remains of two temples dedicated to Zeus and Astarte. There are numerous castles in the area which date back to the Crusades. The White Castle at Safita, the Al-Marqat Castle and the Krak des Chevaliers, the most famous and best preserved of the castles of the Crusade period, were all inspected during the mission.

4 Goals and Methodological Choices

During previous WPs, graphic, cartographic, iconographic and bibliographic material was gathered for pilot sites and so, after an inspection, it was possible to define the area on which to concentrate the on-site research. Studies by G. A. Neglia and M. Bouteflika were used as references for the urban analysis of Tartous and the surrounding area; the “Memorandum on Sustainable Urban Development in Syria” and the “Workshop on the preservation and development of the old city of Tartous” held by GTZ and the Syrian Ministry of Local Administration and Environment, provided information on guiding principles and programmes in the important areas of urban policy and management.

The on site research was conducted in accordance with the WP4 objectives: on the one hand a survey campaign was set up to acquire metric and qualitative data on the structures chosen as samples; this provided the necessary information for the systematic analysis (chronological phases, construction techniques, state of preservation) required for preparing conservation guidelines; on the other hand an enormous amount of photographic and video documentation was collected for the 3D models that were produced in the first phase; this documentation is being used for multimedia popularization and communication of the most interesting sites: architectural heritage, landscape and archaeological sites.

In particular: integrated topographic and laser scanning techniques were used to provide a metric survey of the Knights’ Chapel and the urban spaces inside the Citadel; the most interesting parts of Tartous (the Citadel and the Cathedral/Museum)

and the surrounding areas (Arwad Island and the archaeological site at Amrit) were photographed for modelling for communication projects (virtual tours, integrated video and multimedia products).

4.1 Metric and Thematic Survey

The metric surveys and the studies of the materials and construction techniques were mainly carried out in the old city of Tartous. The urban fabric has a complex structure because of its pronounced vertical stratification. The Knights' Chapel and the cross-vaulted galleries, both situated in the inner circle of the city walls, and a part of the wall circle (Figure 1) were chosen because they have best preserved the peculiar characteristics of Crusader architecture. Three-dimensional metric surveys were carried out to obtain the disposition of masses on an urban scale as well as the detail required for analyzing wall textures. A topographical network with 7 vertices was defined to measure, 59 topographical targets which were necessary for the alignment and referentiation of the range maps acquired. An HDS6000 phase-based scanner was used for the detail survey. The shooting geometry and the scanning resolution were modulated to better adapt them to the morphological characteristics of the spaces. Data was acquired from different view points to ensure uniform data coverage and to minimize any possible "shadow areas". Documenting the Chapel's morphometric characteristics, the building techniques used, the extrados of the vaults, the fallen down parts and the thickness of the walls was a complex business partly because it was difficult to obtain access to the adjacent private spaces but also because it was difficult to transfer the reference system around the building. A total of 43 scans were carried out: 20 for the Knights' Chapel, 7 for the Ottoman galleries, 5 for the portion of the town walls and 11 to document the urban fabric in which these structures are inserted.

In the parts that have been studied it is possible to measure the size of the ashlars, their shape, the workmanship involved and the construction criteria used. A wide variety of wall building techniques has been documented. As an example: portion of wall from the Chapel is made up of perfectly squared parallelepiped blocks, the norm for important buildings; portion of wall from the service galleries, is composed of small blocks of rather irregular shape in a homogeneously textured wall surface.

4.2 Image Recording

All the sites that are part of WP4 – the Cathedral/Museum of Tartous, the Citadel, the Amrit site and Arwad - have been documented using the most innovative digital techniques available to produce spherical panoramas, high resolution image mosaics and digital stereo images. More than 14.000 photos were taken to cover the different aspects of the mission: they show the places, the architecture, the landscapes, the residents and the local handicraft production as well as documenting the different stages of the work. A panoramic head, combined with a 15 mm fish-eye lens, was used for photographing complex or particularly wide spaces that could not be covered by a single photo and panoramas were elaborated using cylindrical equirectangular projection. The individual photos were mounted using software so they could be visualized as 2D files and explored as immersive environments. About 70 panoramas were mounted: each one was made up of an average of 21 photos and a maximum of 60 photos. Up to 3 stop bracketing was used for every single photo: these multiple shots

also make it possible to obtain images with a colour depth of 16 bits and to recover under or over-exposed details. This process is fundamental for 360° external photography where the exposure differences are particularly strong and to obtain HDR (high dynamic range) images.

5 Graphic Output

The total points model obtained after the alignment and referentiation of the range maps is an extremely versatile 3D database as it allows graphic output to be modified to meet specific requirements. Extracting information from the data gathered by the scanning systems is a complex time-consuming post-processing operation that requires special software and skilled personnel. The following information can be obtained from the range maps: plans, elevations and vertical sections; 2D images of the range map; 3D static and dynamic digital models. Further information can be obtained from the photographic archive: spherical panoramas; high resolution image mosaics; digital stereo images.

Table 1. Summary table of metric survey and image recording data

METRIC SURVEY DATA (Tartous Citadel)	
Tartous Citadel total area	about 31.000 mq
Survey area	about 6.900 mq
Surveyors	4
Topographic survey	
Total station	Leica TCR 303
Closed traverse	1
Open traverse	1
Vertices	7
Least-squares adjustment (stdev)	80 ^{cc} , 11 mm
Laser scanner survey	
Laser scanner	Leica HDS6000
Laser scanner stations	43
Acquired targets	59
Acquired spatial coordinates	185.018.130
Registration mean absolute error	0.006 m
IMAGE RECORDING DATA (Tartous and surroundings)	
Photographers	2
Cameras	Nikon D3, D90 and D700
Fixed lenses	15mm f/2.8, 24mm f/2.8, 50mm f/1.4
Zoom lenses	18-200mm f/3.5-5.6, 18-55mm f/3.5-5.6, 24-70mm f/2.8
Image resolution	D90: 4288x2848 - D3 and D700: 4256x2832
Photographed locations	16
Avg. number of photos in panoramas	21
Shots for each picture	3
Avg. panorama resolution	360°x80°: 6.000x3.200
Max panorama resolution	360°x40°: 72.000x3.600
Texture pictures	160
Camera and video shooting time	42'33"

Repeated elaboration of the data collected makes it possible to extract a wide range of graphic output whose complexity and articulation depends on the goal desired and to experiment ways of representing this output that have enormous communication potential: 3D digital modelling as a method for checking the historical reconstruction; 3D and kinetic digital modelling as a tool for understanding and for education and communication; 3D digital modelling for representing morphological transformations. The preliminary results of the surveying campaign undertaken in the Tartous area during WP4 of the Mare Nostrum project are presented below.

A. Plans, Elevation and Vertical Sections The following drawings have been produced:

- A plan (Figure 2) which was realized by integrating a previous survey of the Citadel with the survey undertaken by our working unit. This mixed plan was completed with an orthogonal image of the range maps of all the connecting areas (lanes and the main square) in order to show the extension of the on-site data acquisition.
- Vertical sections (Figure 3) to analyze the urban morphology and the relationship among the buildings.

B. Bidimensional Images Obtained from the Range Map. A precise digital model can simulate 2D images so well that the human eye cannot distinguish these images from perspective photographic representations. The 2D image shown in Figure 4 is example of the remarkable levels of detail that can be obtained using scanning systems. Obviously, temporal information i.e. the condition of the object at the time it was surveyed, is collected along with the geometric information.

This peculiarity, intrinsic to laser scanner data, has many positive uses for both research and for setting up multimedia instruments for popularizing, promoting and explaining the project to different user categories).



Fig. 2. Integration of the existing plan of the present situation and the plan extracted from the points cloud

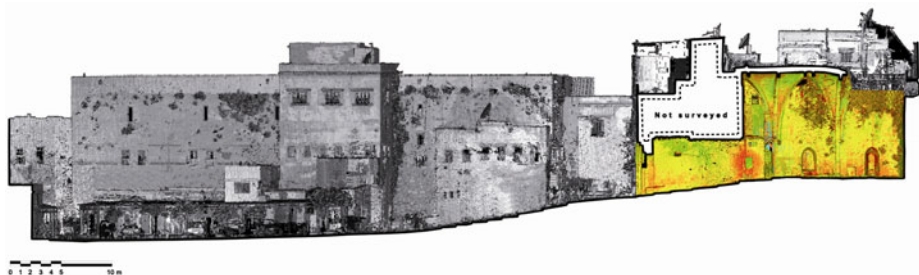


Fig. 3. Transversal section BB' passing through the Knights' Chapel

C. Static and Dynamic 3D Models.

The capacity of 3D models to remain unaltered over time and their interactivity, which allows users to extract information (2D and 3D), makes such models ideal instruments for setting up virtual museums which popularize and explain the museums' contents. But this is only one of their possible applications. As these models possess the fourth dimension, time, they introduce a dynamic element to both representation and comprehension. This factor is extremely important as it provides a method for checking historical reconstructions and for representing morphological transformations.

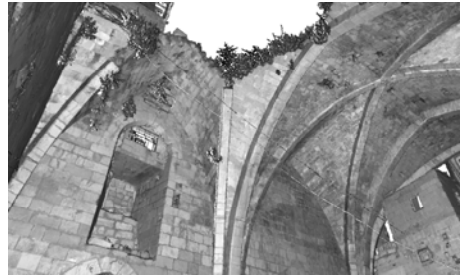


Fig. 4. 2D image of the total points model of the Knights' Chapel

D. Panoramic Images. The images were organized in a database managed by Adobe Lightroom 3. This software allows the images to be catalogued using metadata, i.e. series of information connected to the files containing the images. Some of this information is memorized when the photo is taken, such as the date, the type of camera used, the lens focus, the time and the diaphragm. Other information can be defined subsequently by designing a suitable thesaurus. About 60 keywords have been identified for cataloguing the images belonging to this project which means it is now possible to undertake detailed research within the database. This method of management has made over 30 GB of photographs accessible to the various members of the work group and will also make it possible for researchers outside the WP4 group to rapidly find images. The position from which the photos were taken is also known thanks to the GPS system connected to the camera. This type of information, known as geotagging, facilitates the use of these images allowing them to be managed in innovative ways such as classifying them on the basis of geographic proximity. The elaborated panoramas (Figure 5) can be used in various ways: to enable the use of inter-connected virtual spaces on the internet or on CDs; to integrate chromatic information with the points cloud; in pairs for photogrammetric restitution (spherical photogrammetry).



Fig. 5. Spherical panorama inside the vaulted galleries (Citadel of Tartous)

The panoramas of the most important archaeological and cultural sites in Tartous will be connected and put on line and, in the future, meta-nodes will be used to do the same for the principal Phoenician Mediterranean ports.

6 Towards a “Shared Cultural Mapping”

There has always been a direct relationship between tourism and cartography: maps of travel routes and general information about the areas to visit are used in selecting the destination and in planning travel and stay. Today cartography is numerical and is used on line. Geographically referred data can be questioned, cross-checked, up-dated and it can be a valid tool for understanding and valorizing planning activities as well as informing and preparing visitors. Cultural mapping is a process of collecting, analyzing and synthesizing information in order to describe the cultural resources, networks, links and usage patterns in a community. The technological revolution has had an enormous impact on the information content available on-line and has given rise to the phenomenon known as user-generated content (UGC). Photos, films, audio and text comments are placed on blogs, podcast guidebooks, social network sites, shared content multimedia sites and Wiki at an uncontrollable rate, allowing an undefined audience to access contents that would not have previously been available unless the places described had been visited in person. This enormous amount of content helps to form opinions among internet users regarding tourist destinations and services offered and in fact influences the choices made by future travelers. These technological innovations are opening the way for so-called virtual tourism which lets potential travelers anticipate their travel experience thereby stimulating their curiosity and increasing their interest in the areas visited.

Making a cultural mapping involves many different categories in a participatory approach: residents, administrators, schools, tourist operators, and generates new perspectives and prepares the ground for effective cultural planning. A map has much greater potential than an inventory; it communicates a rapidly increasing amount of information and appreciation, it draws attention to the cultural area identifying previously unknown resources and activities, it provides the possibility of looking at data from different perspective thereby gaining objectivity and overview and of locating gaps, needs and overlaps. The work to be undertaken, in the EuroMed Mare Nostrum project, will contribute to programming sustainable development by helping transform tourism into an element that valorizes the environmental and cultural qualities of a given territory as well as consuming them. The future of the tourist industry depends on the conservation of the environment in which it takes place. The first steps required are: to increase the awareness of the population regarding the cultural heritage of their own country, to sensitize visitors and to train tour operators. A series of innovative and experimental measures should also be taken in order to identify strategies and instruments for reducing the pressure of tourism on the environment and for improving the quality of the environment in areas that will remain mass tourism destinations (for example the Island of Arwad where the visible degradation is due to the large numbers of visitors).

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VISMAN-DHER Project: Integrated Fruition of Archaeological Data through a Scientific Virtual Model

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Abstract. This paper presents a Virtual Archaeology application realized using ViSMan (Cineca), an open-source framework for visualization and interaction with scientific 3Dmodels connected to digital archives of data. The source for data was research project (survey and documentation, study and communication) carried out by the University of Bologna in the archaeological sites of Pompeii and Herculaneum. Through a collaboration with Cineca VisITLab - experienced in virtual environments design for research and education purposes - virtual models were used as 3D archive for management and visualization of this huge amount of relevant data, thus developing a spatially structured interface for data retrieval and contextualization. The implemented application - ViSMan-DHER - allows navigation through several reconstructed Scenarios; access is provided to a rich archive of data, related to the whole region territory as well as pertaining to a single wall-painting. Some remarks and hints for future development are listed in the conclusive section.

Keywords: Herculaneum, Pompeii, Roman Houses, Scientific Visualization, Virtual Archaeology, Virtual Models.

1 Introduction

Virtual models in archaeological and historical research - provided that they are realized with philological accuracy and clear cut procedures - can perform a variety of functions, like the management of documentary material (as, for instance, in reconstructing a stratigraphic sequence of an archaeological site), providing graphic support for analyses, setting tools for museum and educational purposes as well. A well-structured virtual model can be used as a 3D archive for visualization, organization and analysis of heterogeneous data [12].

New features have been introduced in scientific VR application according to this perspective: hyperlinks from the model to external datasets (including sources and related documents), integration with relational databases, metadata management, better user interaction, multi-channel communication projects, sharing through educational platforms or ePublishing through online archives.

Providing access to metadata and external information is a key point in making 3D models useful and reliable tools for research - not only for communication - in Cultural Heritage. Of course the data collected have to be made uniform, and connected to the model or to its parts, that is often a time-consuming activity and requires interdisciplinary skills.

3D models have not so far experienced the expected widespread use, especially within the scientific community, which still doesn't consider them valuable tools of research. Hopefully, in the next few years 3D models are set to be shared storage and exchange formats for data, both in the internet and outside it.

This paper analyses an ongoing Virtual Archaeology project, starting from the archaeological study that originated it and from previous similar experiences of the main institutions involved. In order to manage a rich archive of heterogeneous data, a set of 3D virtual environments was chosen as a metaphor for representing and exploring data while keeping spatial relationships and context. For this purpose a dedicated application (ViSMan-DHER) was developed, based on an open-source framework for virtual scenarios visualization and management called ViSMan [4], [24]. Structure and concept of the application are briefly described, together with lessons learned and some future perspectives.

2 Previous Experiences in Virtual Archaeology at VisITLab

Cineca [18] is a Consortium of Italian universities, and the largest Italian computing centre. In 1988 it was equipped with a Virtual Theatre and created a dedicated Laboratory, the VisITLab (*Visual Information Technology Lab*), that in the last decades carried out experimental projects in various fields of research, promoting the use of Computer Graphics and Virtual Reality applications for scientific data visualization and management. Many projects concerned Cultural Heritage and were developed in collaboration with the University of Bologna [13], [15].

With the massive diffusion of Computer Graphics, Virtual and Augmented Reality, mostly encouraged by the videogame market - and recently by geo-information industry - new possibilities and new needs have arisen from the scientific community, above all the needs of easy-to-use tools for the visualization and management of virtual environments, specifically designed for Virtual Heritage and providing users with the possibility not only to navigate 3D models, but also to extrapolate information about reconstructed objects. External data, related to a scientific model, are often necessary in order to attest the huge research activity preceding reconstruction, to ensure correct methodology and data reliability, and to certify its authors and origin. Of course this applies both to metadata and to heterogeneous datasets, spatially or contextually related to the reconstructed structures, such as pictures, drawings or texts. 3D data, on the other hand, can act as an intuitive and spatially structured interface for a better exploration and organization of connected data, contextualizing and showing the objects to which they relate.

Of course video-game hardware and software focus on reconstructed words without allowing management of external references; scientific tools such as GIS (*Geographical Information Systems*) and CAD (*Computer Aided Design*) software do manage complex databases but they don't support interactive navigation of complex

virtual environments. Moreover, these tools require users a remarkable learning curve and they need high license fees.

2.1 The Development of ViSMan Software

In order to fill this specific gap, Cineca developed ViSMan (Virtual Scenarios Manager) [4], [24], an open-source framework based on OpenSceneGraph [21] graphic libraries and written in C++ language. ViSMan tends to use open source libraries and resources for every functionality, and presents an open, modular and thus extensible architecture that allows flexibility, integration of new modules and easy updating.

ViSMan is basically a visualization software for virtual environments, provided with an intuitive “video-game like” browsing interface. During navigation it is possible to create relevant points of view, to assign names and create automatic paths between saved points. The 3D world supports ground and surface collision, thus allowing to follow uneven terrain or stairs in an enhancing first-person perspective.

When different models need to be compared or superimposed, switching between Scenarios is possible. This “switch” feature is particularly important to historians and archaeologists, who often deal with reconstruction of landscapes or structures changing over the time, or with alternative hypothesis that need to be compared, or just differentiated according to their reliability degree.

Still, we think the most important feature in ViSMan is the connection between 3D objects and relational databases, just like a GIS does with geo-referenced 2D data; by simply clicking an object or part of it on the stage the user accesses a hyperlink to an archive of multimedia content, such as HTML, texts, images, videos, audio tracks, web-pages and even the results of dynamic scientific visualizations and simulations [14]. Data can be visualized in a custom format and connected to remote databases through the Internet. Starting from a query performed into external data, on the other hand, it is possible to generate polygonal writings or labels into the scene starting from database records (exactly as happens in a traditional 2D GIS), to search objects in the 3D model by selecting them from a list, or just to perform queries in the data-system.

Features of the software are currently being updated, along with the evolution of Virtual Reality into a tool for research and analysis of data.

Examples of Cultural Heritage projects where ViSMan proved its efficacy are Museo Virtuale della Certosa - developed for the municipality of Bologna [19], and VisArq. 1.0. on the archaeological area of Zaragoza (Spain) ([10]; see more case studies in [15], [11]).

The former is a database of images, letters, pictures and witnesses relative to citizens buried in the monumental cemetery of Bologna, that can be queried through an interactive map on a website, through a detailed virtual model of the monumental complex, or simply browsed on a website.

The latter instead is an online catalogue of heterogeneous data coming from a great number of archaeological sites in the Province of Zaragoza, Spain. During real-time (off-line) navigation of a Digital Elevation Model of the territory, relevant sites can be selected and connected data visualized through a HTML web interface and queried in a structured database.



Fig. 1. Virtual model of the Certosa explored with ViSMan

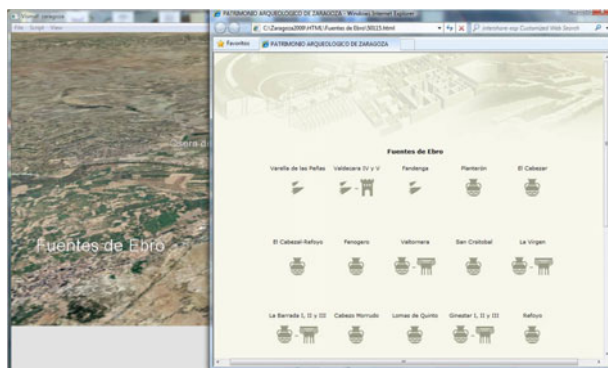


Fig. 2. A screenshot in VisArq 1.0 application; territory DEM inside ViSMan and HTML interface for online database

2.2 Towards Multichannel Communication

As stated above, VisITLab tested different solutions for scientific visualization employing Virtual Reality applications and especially ViSMan software.

However, the same virtual environments, realized by and for researchers, were used for communication and educational purposes as well, e.g. providing high quality renderings as contents for exhibitions and multimedia communication products. Well-built, interdisciplinary teams had to be employed in order to realize these experiences. The starting philological virtual models were declined into narrative contents for applications to be distributed over different media, ranging from palmtop devices to the Internet and from immersive real-time navigation experiences to video recording in a Virtual Television Set (see below).



Fig. 3. Prof. Scagliarini interviewed in a Virtual Set for the “High-Tech Pompeii” documentary (2000), with the virtual House of Centenary as background

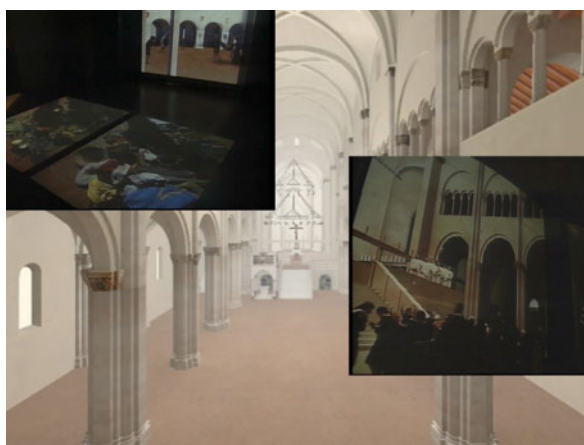


Fig. 4. Philological model of the Parma Cathedral, and video installations showing use of models in a Virtual Set, populated with life

The virtual model of the House of the Centenary, originally set as a support for data and a test bed for reconstruction hypothesis by the University of Bologna, was then used as a Virtual Set where real actors seemed to interact within the model; actors are actually playing in a special television Studio in front of a blue screen, and the video recording is composed in real-time over rendering images from the model. A documentary titled “High-tech Pompeii” was realized for the Italian Public Television (RAI).

A museum exhibition, “Living in the Middle Ages. Parma at the time of the Cathedral” was also realized employing a Virtual Set: real actors animated the philological models of the cathedral and the main square of the city. Videos were later used to realize three immersive multimedia installations that took the public on an imaginary journey through time, allowing understanding of daily life in medieval times.

These experiences, besides creating synergies and collaborations among different specialists, highlighted the possibility to transform philological models into didactic spaces and into engaging narrative for the general public. Virtual models - initially built with philological care but paying little if any attention to communication - developed into narrative and didactic spaces, with the introduction of characters and the use of storytelling techniques.

3 The Work of the University of Bologna at Pompeii and Herculaneum

The University of Bologna and Cineca VisITLab have been collaborating since 1990, in many Virtual Archaeology projects, like NUME (*Nuovo Museo Elettronico della città di Bologna*) [3] [22], MUVI (*Museo Virtuale della Vita Quotidiana*) [9] [16] [20], Pompei - Insula del Centenario (IX, 8) and DHER (*Domus Herculaneensis Rationes*) [5].

Among these, Pompeii - Insula del Centenario (IX, 8) and DHER are part of the Vesuviana Project, that the University started in 1997 in collaboration with the Soprintendenza of Pompeii and Naples [6] [8] [23].

The Pompeii project (1997-2005) consisted in a detailed and manifold system of documentation, analysis and publication, carried out in Pompeii's Insula IX [5] [7], while DHER (2005-2010) is extended to a whole urban center, the archaeological site of the ancient Herculaneum [8].

The focus of the Herculaneensis project is on the study of domestic architecture and housing culture, through two main lines of action: a new campaign of documentation of the decorations (pavements and walls) and the complete analysis and publication of case studies. As starting step, Insula III and its main buildings (especially the so-called House of the Skeleton, House of the Bronze Herm and House of the Wooden Partition...) were studied in detail, and with a multidisciplinary approach.



Fig. 5. Archaeological area of Herculaneum [17]

Such a complex field work ended up with the generation of a huge amount of material, partly recorded on site and partly retrieved from archives by an interdisciplinary team that flanked the archaeologists: specialists in archives, in archaeometry, materials, topography, geology, conservators, structural engineers and multimedia technology specialists, even filmmakers and communication experts.

This amount of data had eventually to be organized and structured in order not to be lost or dispersed. An easily accessible mean for visualization, consultation and even comparison among heterogeneous data had to be implemented, while keeping complexity and relationships between external data, analyzed structures and archaeological context.

4 The ViSMan-DHER Application

4.1 Purposes and Methods

An application based on ViSMan was developed at Cineca VisITLab for the DHER Project. The framework aimed at allowing not only archeologists who had been working on it, but also external researchers, students and specialists to obtain visualizations and to query into the archive created throughout the DHER project, [1] [2].

Since collected data referred to very different contexts (starting from the whole territory and getting to the detail of a single wall-painting) the metaphor chosen for visualization was the creation of some whole virtual environments (called **Scenarios**) with growing level of detail. Each different Scenario gives access to a dedicated section of the database, so that information detail varies according to the reconstructed level that the user is exploring.

In documentation as well as in the virtual models it was necessary to set a “unit” for data visualization: the extent of this unit changes according to the context that is being explored.

In a whole urban area Scenario units are constituted by Insulae and houses, while inside detailed reconstructions of houses rooms or single wall-surfaces were preferred.

These elements were marked as **Nodes** in the OSG file - and linked to the available types of data.

Different Scenarios are interconnected through the *switch* feature of ViSMan (see above) and according to a logic and spatial hierarchy.

A standard navigation session in the application should involve the following steps: navigation through the territory Digital Elevation Model, choice of one archaeological area (Pompeii or Herculaneum), visualization of the representation of the city, including some Nodes (Insulae and houses), query to the database to know which data are available for a certain Node, visualization of the data (e.g. images), switch to a new Scenario (a reconstructed house), query and visualization of data associated with single walls or rooms.

4.2 Application Structure

Virtual models were realized in OSG format and grouped into few **Scenarios** (Territory of Campania region, Archaeological areas of Pompeii and Herculaneum, and some detailed reconstructions of roman houses).

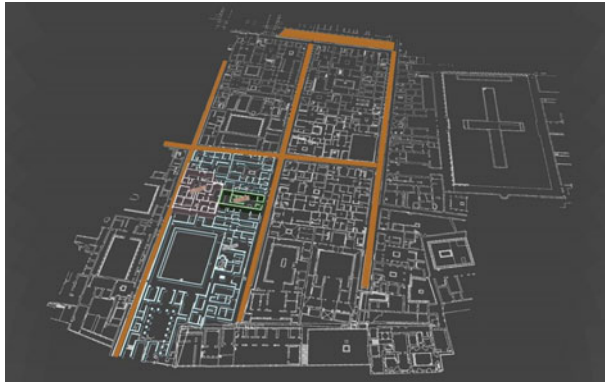


Fig. 6. Scenario “Archaeological area of Herculaneum” with Nodes representing houses and Insuale

In order to connect reconstructed objects to items in the database, the **Nodes** have been devised: a Node is a virtual model or a group of geometries inside a Scenario that has been associated and linked to one or more items or records in the dataset.

A relational database was implemented, containing reference to Nodes and to the corresponding items in an archive of images, texts and documents.

Each type of data pertains to a distinct table in the database, while each single document is a record. Most of them only consist in text, or image and caption, but some are more complex and for each one a simple visualization interface was developed in ViSMan.

The following categories of data were included:

- Photomaps of wall decoration
- Analytic description of wall decoration
- Excavation journals
- Photographs of findings
- Analytic description of findings
- Graphic documentation from the Archive of the Soprintendenza
- Photographs (by Foglia, 1992) from the Archive of the Soprintendenza
- Historic photographs from the Archive of the Soprintendenza
- Restoration journals (1996)
- Survey data: Masonry Stratigraphic Units (USM)
- Survey data: Photomap of the walls

Data formats are JPEG images, TXT text files and PDF documents, but more format are supported by ViSMan and might be included in the future.

Two specific solutions were found for the reconstruction of Roman houses.



Fig. 7. Realistic virtual reconstruction of the House of the Skeleton as it looks today was used as a spatial interface to access survey and archive data

The so-called House of the Skeleton, in Herculaneum, showed a particular situation, with the most rich and complete dataset coming from architectural survey and masonry analysis. The structure had been carefully geo-referenced, surfaces and volumes had been documented through survey, monoscopic and stereoscopic photogrammetry of walls, Masonry Stratigraphic Units with restorations and modern integrations had been mapped. Furthermore, a detailed and realistic 3D model was also included, realized from survey and textures photogrammetric images.

In order to exploit this wealth of data, the model was modified with Autodesk 3D Studio Max (later with the open source modeler Blender) to optimize it for real-time navigation and integrated into ViSMan-DHER application, thus becoming at the same time the visible representation of the survey and photogrammetric data, and an intuitive spatially organized interface to reach other data.

Other houses, instead, smaller and simpler than the former, presented interesting archive and field data, but no previously built virtual model. In this case undertaking the realization of a detailed 3D model only as support for data visualization seemed to make little sense. Furthermore, it has to be stressed that for research purpose first any virtual model should be functional and effective as a representative model, while realism and completeness comes second, provided that spatial and context information and relationships are conserved.

For these less complex buildings a meaningful level of detail for data organization and visualization was set to the single room, instead of the single wall surface.

This is of course the most common situation for the studied structures in Herculaneum and Pompeii, so a simple and flexible solution had to be thought out to allow future application to further case-studies.

Eventually the choice was to model simplified representations of buildings, just extruding their plan, and keeping division into rooms as different Nodes.

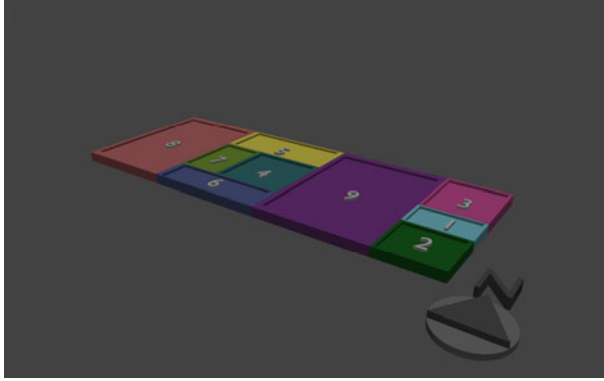


Fig. 8. The House of the Bronze Herm was represented through a schematic model of its room distribution

4.3 Lessons Learned and Perspectives

Once that experiments have been performed to verify the feasibility of this product, that is applying it to the specific case study of the DHER project, the second phase has been started. This still ongoing phase involves the team at work as well as all the other équipes.

Such a “sustainability” assesment goes along with new data acquiring.

At present the product shows to be an essential tool in the procedure system of the DHER project. In particular, it has proved to be a valuable tool to the interpretation of the documentary basis. This is a further proof of the role that 3D visualization, connected to searchable as well as verifiable databases, can play in archaeological research enhancing the potential for understanding the evidence. It has to be stressed that particular operating and methodological choices, that we believe to have rightly made in conducting the experiment, have revealed to be of fundamental importance for its success. Among these we can say that data sharing enables full and potentially endless examining of the documentary basis, both with the team at work and, in perspective, to the whole scientific community.

Successful implementation of ViSMan-DHER application shows how Virtual Environments can evolve into a research tool for archaeologists, as it allows visualization and simulation of concepts and context relationships that would otherwise be theoretical and hardly communicable, at the same time ensuring scientific accuracy of historical reconstructions through documentation [1] [2].

Anyway, while the software architecture, the dataset and the back-side of data management by researchers are firmly established, more work is required on the front-side of final users fruition and interface.

For instance, navigation is currently controlled through keyboard or through a simple navigation bar, but it can be made substantially more user-friendly. Actions such as querying available data types for Nodes or switching between models and data are controlled through a mouse-controller, but could as well be made far more intuitive with the use of instructions or popup labels.

Moreover, direct access to software settings, editing of paths, point of view, and ground collision, while very useful during assemblage, could be preset and thus removed from end-user interface or substituted with few defined options, in order to simplify the navigation experience.

Data visualization is now managed through a very simple frame, that could be improved e.g. by implementation of new functions (such as more complex queries in the database), or greater freedom for the researcher/user on data display.

Target users, as stated above, should include not only the DHER Project team, but also external specialists and students, with different levels of skills both on 3D navigation and on this specific archaeological area. For this purpose a strong work on software documentation and graphical interface is being carried out by ICT specialists at Cineca, together with archaeologists.

Distribution and fruition of contents developed with ViSMan is also a major aspect to be fixed in the next months. Initially, a temporary solution proposed for display to the public was a double monitors: one was used interactively through keyboard and mouse-controller for interactive navigation of the three-dimensional models, the other one was simply joined to automatically display images and other data recalled by queries to the database.

The whole system is currently accessible off-line on performing Personal Computers, and in immersive environments, such as the Virtual Theatre at Cineca.



Fig. 9. A screenshot of data and model navigation inside Scenario “House of the Skeleton”

Future development in distribution publication will probably be a stand-alone application distributed on CD-Rom, but testing of new channels for distribution is also scheduled: above all, other projects realized with ViSMan have shown that on-line hosting of the 3D models, database and contents are an effective channel for communication, allowing great personalization of the interface, and integration or linking to existing projects and institutions [16].

As far as contents are concerned, further progress can be either quantitative growth in information, with the integration of more items in the already existing types of data (e.g. data pertaining to new houses), or creation of new typologies.

5 Conclusions and Remarks

New technologies in Cultural Heritage data management and visualization are valuable assets both for research activity and for data sharing and dissemination, as long as they are included in research projects from the very beginning. At the same time, strong attitude towards interdisciplinary work, flexibility and basic communication and IT skills are required for archaeologists and researchers who want to move in this direction.

Finally, previous experiences carried out by VisITLab in the field of Virtual Reality applications took us to the conclusion that we should start evaluating educational effectiveness of these tools with the support of cognitive psychology methodologies. Also in this sense, a migration of the application to the Web would provide access to a much richer range of tools for user profiling and usage evaluation.

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Teleimmersive Archaeology: Simulation and Cognitive Impact

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Abstract. In this paper we present the framework for collaborative cyber-archaeology with support for teleimmersive communication which aims to provide more natural interaction and higher level of embodiment. Within the framework we create tools for exploration, interaction and communication of archaeologists in a shared virtual environment. Users at different geographical locations are captured by a set of stereo cameras to generate their real-time 3D avatars. The proposed framework is intended to serve as a virtual simulation environment where advanced behaviours, actions and new methodologies of research and training in archaeology, cognitive science and computer science could be tested.

Keywords: Cyberarchaeology, Teleimmersive Remote Collaboration, Shared Virtual Environments, Cognitive Impact.

1 Introduction

Teleimmersive Archaeology is a joint research project between the University of Berkeley (Teleimmersive Lab) and the University of California, Merced (Virtual Heritage Lab), supported by a CITRIS grant. The scope is the creation of virtual collaborative systems using teleimmersive technologies for real-time performances in the interpretation and reconstruction processes in archaeology. The methodological approach is based on the simulation process, in other terms on the idea that cyber-archaeology constitute the core of the interpretation capabilities in the digital simulation of the past (Forte, 2008).

One of the key issues in the collaborative-participatory activities is the role and the behaviours of all the actors involved in the process. Therefore factors such as the sense of presence, embodiment, gestures, interaction, motion capture, spatial sharing, 3D design and virtual tools influence deeply the level of learning and communication.

In the last decade several projects can be counted in this field: ARCHAVE (Acevedo et al., 2001); VITA: Visual Interaction Tool for Archaeology (Benko et al., 2004); SHAPE (Hall et al. (2001), LAVA, Laconia Acropolis Virtual Archaeology (Getchell et al. 2009). In addition other projects have explored the educational potentialities of the virtual communities such as Second Life (Nie, 2008). Further applications

have been focused on the 3D Web collaborative systems such as the case of the FIRB project (Forte and Pietroni, 2008), using Virtools DEV and Virtools Mutiuser Pack© by linking three different archaeological sites. In this case, all collaborative activity was online and with pre-determined 3D graphic libraries.

Although the massive multi-user environments seem appealing for such applications, they are currently unable to provide users with truly immersive experience or sufficient flexibility to construct the type of complex framework that we propose. The users of the former technologies were mainly observers of virtual replicas of ancient worlds, not active participants contributing to the reconstruction and interpretation processes.

2 Teleimmersion

Achieving an immersive experience in collaborative environments requires providing a visual experience similar to that delivered by reality. Traditional immersive virtual reality systems often use avatars, to represent human users inside the computer generated environments. Pre-modeled avatars, however, have several limitations with respect to body movement dynamics, gestures, eye contact and other subtle communication via body language and facial expressions. Likewise, the existing video conferencing technologies fail to properly preserve the eye gaze which has been shown to be an important factor for remote video-based communication (Fullwood and Doherty-Sneddon, 2006).

In our work we move further from the avatars and apply stereo reconstruction to capture 3D representation of users in real time to facilitate visual experience similar to reality (e.g. face-to-face meetings), where users are able to establish eye contact and use their body to communicate and interact (e.g. pointing at objects). The developed 3D reconstruction framework has been successfully used previously in remote dancing applications and learning of Tai Chi movements (Bailenson et al. 2008).

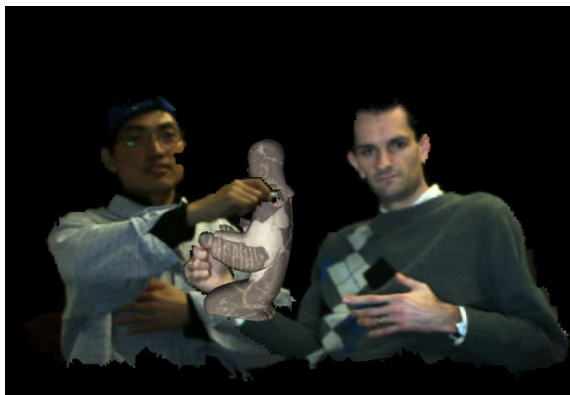


Fig. 1. Two users are interacting with a laser scanned statue in a shared virtual environment. Integrated 3D video provides a virtual position of each user, allowing users to point at different features of a 3D model as if they were sharing the same physical space.

3 Framework Overview

Our cyberarchaeology framework seamlessly combines computer vision and virtual reality (Fig. 1). The prototype application supports rendering and interaction with various 3D models, real-time interaction with different input devices, exchange of multi-media data streams for communication (i.e. audio, video and 3D video). The collaborative framework is built upon Vrui VR Toolkit, developed by Kreylos (2008) at University of California, Davis, which can run on a wide range of virtual reality hardware with support for different display and input device technologies.

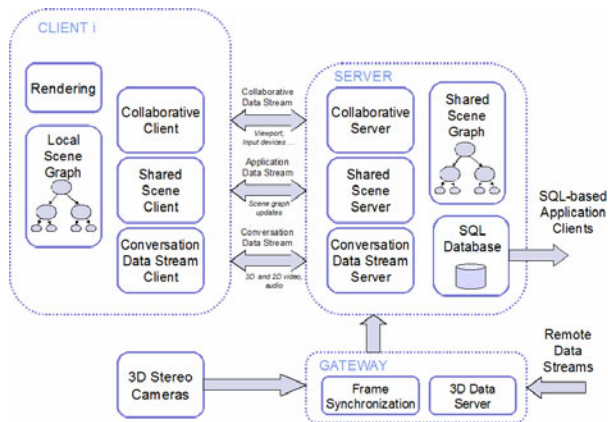


Fig. 2. A simplified block diagram of the 3D teleimmersive application for collaborative interaction in a shared virtual environment

3.1 Shared Scene Graph

The collaborative virtual environment is based on shared scene graph to describe the spatial relationship of objects and facilitate interaction between remote users. The scene graph is maintained on a central server which can connect to a spatial database. Whenever changes are made to the scene (e.g. adding/deleting objects, moving objects etc.), the clients receive the updates for their local scene graph representations. The scene graph also allows for efficient rendering. Current implementation with vertex buffer objects allows for display of 1 million triangles with the frame rate of 60 FPS (GeForce GTX 8800 graphics card).

The scene graph encodes different properties of the scene (e.g. geometry, texture, metadata) through a hierarchical scheme of inter-connected nodes of different types as follows:

Transformation Node defines position and orientation of its child nodes with respect to the other transformation nodes higher in the hierarchy. The transformation is described with six parameters. Nested nodes allow objects to be linked together.

Geometry Node describes object geometry through a list of vertices and a list of indices of the corresponding triangles. The data is used for building vertex buffer

objects (VBO) which allow for efficient rendering. The geometry node also encodes the object bounding box, which is used for the collision detection.

Texture and Material Nodes are comprised of object textures and material properties. Several high resolution texture file formats are supported in the application. The textures can also be dynamically switched, for example to alternate between the original and reconstructed surface of a wall painting. We implemented the surface material properties defined by the OpenGL standards.

Object Node is a group node that can incorporate several geometry and texture/material nodes defining a particular object. The clients currently support only OBJ/Wavefront 3D file format with the ability to use several different texture formats. The object node can be easily extended to support other 3D formats by modifying the file loading function.

Grid/Height Map Node is used to render surface grids for emphasizing different surfaces or creating a height map that defines the landscape of the archaeological dig. The map can be texture mapped with the images of the landscape to create more realistic rendering.

Metadata Nodes support rendering of images and text that can be attached to different artefacts in the virtual environment. The metadata can contain information on object geometry, location, short description, and images. Currently the metadata cannot be edited within the application.

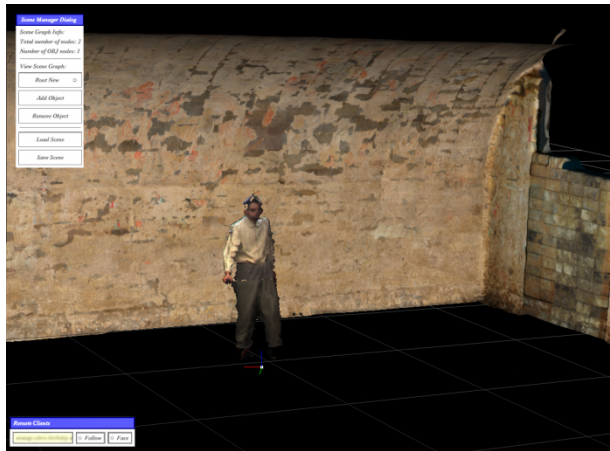


Fig. 3. Locally, users observe the virtual world in the first person perspective. Remote users are represented by their 3D avatars captured by one or more stereo cameras.

3.3 Navigation and Interaction

To explore the virtual environment, users navigate and interact with 3D models in the first person perspective. The presence of the remote users is accomplished through the rendering of their 3D avatar generated by the stereo cameras. The location of their avatar corresponds to the current location of the user's virtual view point.

At any time, individual users can switch to the other user's point of view or select face-to-face mode for direct conversation. The latter functionality will bring the local user in front of the remote user to facilitate a view similar to a video conferencing. Remote users can, however, work independently in the shared virtual environment. To prevent inconsistencies any two users cannot move the same object at the same time. A lock is placed on the node and its children if another user is already interacting with the object. The lock is assigned on first-come-first-serve basis.

The framework in connection with Vrui VR Toolkit features a wide selection of tools for interaction with the environment:

Navigation Tools provide a variety of ways to move around the virtual environment (e.g. flying, surface navigation).

Measurement Tool can be used to perform dimensional and angular measurements to capture the geometry of scanned objects. The measurement tools can also be used to measure spatial relationships between the objects. Fig. 4(a) shows the measurement of features on a small statue from a Western Han Chinese tomb.

Lighting Tool incorporates a virtual flashlight which can be used to relight parts of the 3D scene or point at salient features. The relighting can enhance underlying details of the scanned artifacts. Fig. 4(b) demonstrates the use of a virtual flashlight to enhance spatial details of a laser scanned model of a mask from Mayan city of Copan. In the future we will add ability to place static lights along the scene to more precisely control the illumination of the objects.

Annotation Tool allows users to draw 3D curves to mark different geometrical features and communicate them to the remote users. The annotation tool can also be used to quickly acquire a 2D or 3D sketch of patterns or objects. Fig. 4(c)(d) show an example of sketching the pattern on a scanned tile of a Western Han Chinese tomb and the corresponding geometry.

Dragging Tool is used to move objects in the 3D space. Object picking action is determined through a collision detection algorithm between the dragging tool selection ray and pre-calculated object bounding box. User can interact with an object only if another user has not already picked the same object. Movement of objects in different direction can be controlled independently through a dialog (when using a mouse) or through direct device interaction (when using 6 DOF input device). If the input device tracking and the stereo cameras are aligned, the hand of the avatar will be in contact with the object while it is being manipulated by the user.

Object Selector Tool is used to select objects and perform different actions related to the local functionality, such as changing object rendering style (e.g. texture, no texture, mesh only), retrieving object metadata, focusing current view to object principal planes etc. The selector tool allows selection of several objects simultaneously while different actions can be performed on selected objects.

3.4 3D Video Capture and Rendering

The avatars of users integrated with the virtual environment are created in real-time by the 3D stereo algorithm (Vasudevan et al., 2010). This algorithm performs accurate and efficient stereo computation by employing fast stereo matching through an adaptive meshing scheme. The output of the stereo reconstruction is a 3D mesh which is compressed and sent from each stereo camera to the local gateway. The achievable

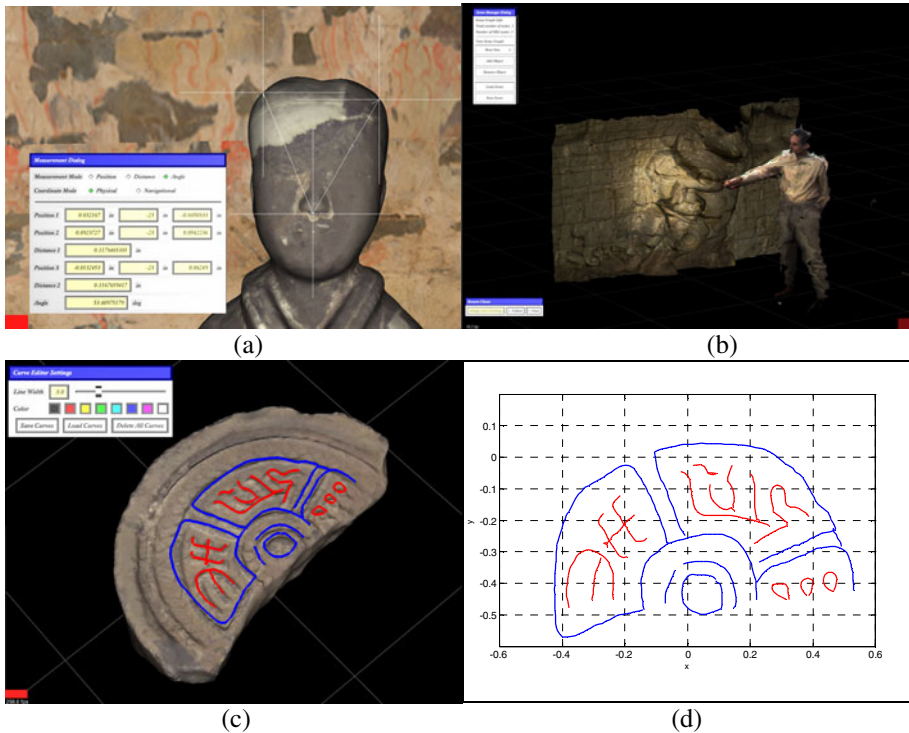


Fig. 4. (a) Dimensional and angular measurement can be performed on the virtual artefacts to capture their geometry. (b) Remote user is interacting with a virtual flashlight to enhance the underlying details of the laser scanned model of a mask from Mayan city of Copan. (c) Annotation tool is applied to mark important features and communicate them remotely to other collaborators. (d) Data from the annotations can be extracted in a form of a 3D sketch for subsequent analysis.

frame-rate is about 25 FPS on images of 320x240 pixels and about 12 FPS on images of 640x480 pixels. The accuracy of the reconstruction and is typically between 1 cm to 3 cm. To increase the fidelity of the reconstructed users, we also apply dynamic texture mapping. Several stereo views can be combined through calibration and blending to increase the workspace of the interaction and to provide 360-degree capturing.

3.5 Results

In this paper we present results from two different experimental setups (Fig. 5) connected over the internet. For the first setup, we used the teleimmersion platform at University of California, Berkeley (Vasudevan et al., 2010), which has several stereo clusters, each connected to a four core server, to perform 360-degree stereo reconstruction. The system is integrated with a tracking system (TrackIR by NaturalPoint) that tracks position and orientation of a Wii Remote (Nintendo). The Wii Remote is used as a 6 DOF input device for interacting with the virtual environment. The second

setup consisted of a single Bumblebee 2 stereo camera (Point Grey, Inc.) positioned above 65" LCD screen. Users were able to interact with the environment with a 3D mouse. Users can change the hardware platform by simply modifying a configuration file.

At this stage, we did some preliminary experiments with the 3D archaeological data coming from a monumental Chinese Western Han Tomb (beginning of the first millennium AD). We recorded and documented the tomb with 3D scanners in the summer 2008 at Xi'an, China. The tomb, now closed to the public (because of serious problems of conservation) after the excavation, is now accessible only virtually. For the teleimmersive system, the tomb was reconstructed by laser scanner data and by the integration of high res textures of mural painting and 3D models of funeral goods (recorded by laser scanning), then re-contextualized in their original positions (Fig. 3). Even the corridor and the three chambers of the tomb have been studied in the collaborative systems, especially the architectural elements, the organization of the space and the relation between iconography, the funeral chambers, and the 3D model. The use of lighting and measurement tools with the capacity to move, share and compare the objects in the cyber space, to add visual layers and outlines in the wall paintings have considerably increased the simulation factors and the faculties for data interpretation. The involvement of different interactors in the cyberspace yielded new perspectives in the dialectics of the interpretation process and its multivocality.



Fig. 5. Two different teleimmersive platforms for interaction with the virtual environment (below) and their corresponding view in the virtual environment

3.6 Cognitive Impact

Cognitive scientists are studying how users interact and manipulate objects in this system. They will track the use and development of the system with various methods of investigation. In the end, the results will be used to develop robust learning tools and to improve the design and use of the system. In one line of cognitive research, the eye movements of multiple users will be tracked as they discuss objects and manipulate objects. Of interest will be how language directs the attention of users. In another line of exploratory research on users, the utility of a pure first person view (no avatar) and a pseudo-first person view (with avatar) will be tested. Here trade-offs related to

allotment of attention, ease of use, and awareness are expected. For instance, because of limitations due to cognitive load, users may visually attend to objects less when they are using an avatar to represent themselves. This will of course have implications for how well users learn material in the environment. However, ease of communication may be better with an avatar because users can point and use other gestures for disambiguating the speech stream. In yet another line of research, we will investigate how and when users point at objects (and locations of objects), including the consistency of their pointing and the spatial characteristics of their pointing.

3.7 Learning Process

Teleimmersive environments afford many learning opportunities because they allow users to collaborate remotely on many different types of projects. One obvious issue to study is how easily users can learn new information presented in the environment, and how to simplify or optimize the learning process. Setting up a robust environment that enables shared learning will allow users to collaborate more efficiently and to collectively learn further new material more readily in the future (for excellent discussion of scaffolding in technological learning environments, see Pea, 2004).

For the first cognitive study, we will use the Chinese Western Han Tomb, which was mentioned above, as learning environment. We will begin with a simple study that offers users either a first person view (no avatar to represent the self) or a third person view (avatar to represent the self). In each of these conditions, we will run 10 participants; each will randomly be assigned to either a director role or to an observer role. After they enter the tomb and get used to the environment, directors will be told to reconstruct funeral objects while the observer watches. To accomplish this task, the director will use a set of tools provided in a separate window. In the first person condition, the director will move his or her avatar to the objects, pick them up, and assemble them. In the second person condition, the director will simply touch the objects, pick them up, and assemble them. In this case, no avatar will be visible (to anyone in the environment). To learn how to successfully put the objects together, the director will look at a diagram that shows how the objects go together but no written text (so there is no explicit order of actions).

The task will intentionally be difficult to engage and challenge the users, and to adequately test for differences in performance. Directors will have as long as needed to complete the task. The director will let the observer know when he or she is finished. At that point, the observer will have to put the object together. Various methods will be used to test the success of learning in the avatar versus no avatar instructional phase.

One prediction is that the first person condition, directors will take less time to construct objects because the director will have a direct embodied experience and not have to worry about how the avatar appears. In turn, the observer who worked with the director in this condition should also perform the task more quickly. We also predict there will be fewer errors with the first person condition because there will not be an avatar to distract the visual attention from the objects and how they are assembled. Yet another prediction is that directors, and in turn, observers, will remember details about the task better in the first person condition because more of their attention will have been allotted to the objects and strategies involved in putting them together. Together, these results will provide valuable information about the utility of the system for learning, and cognitive impact.

Follow-up studies will be developed from this initial study. In one, we will cross the avatar/no avatar condition with user. This will enable us to study efficiency of learning with no avatar under any circumstances versus learning an avatar that can be seen only by the director or only by the observer. We will also extend the initial study to situations with multiple users, and in some cases, multiple users constructing an object together. This will be important to developing a system that takes multiple views and mental models into account. We will also test novice versus expert users of the system to determine optimal modes of instruction given learning stages.

4 Conclusions

The system is in prototypal phase and needs significant work to improve the tools, user interfaces and rendering. This learning platform will teach users how to interpret, reconstruct and communicate archaeological datasets using all the information available in a virtual participatory form, for instance, photos, movies, maps, 3D models, spatial data and texts. In the future, we will study the utility of interactions with avatar/no avatar versus first person interaction. In later lines of research, the eye movements of multiple users will be tracked as they discuss objects and manipulate objects. Of interest will be how language directs attention. Finally we will investigate how and when users point at objects (and locations of objects), including the consistency of their pointing and the spatial characteristics of their pointing. We will also study how well users remember materials they have learned in the environments and how well this information is retained over time.

Finally, the study and analysis of a virtual reconstruction process in archaeology will help the virtual community to re-contextualize and reassemble spatial archaeological data sets, from the first draft version (data not yet interpreted) to the final communicative level. The research activity will involve a bottom-up approach, i.e., the analyses of the archaeological remains as they were found on site, and a top-down approach, i.e., the reconstruction/interpretation of the data by cultural comparisons (for example architectural features, artefacts, frescos, styles, materials, shapes, and others).

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Accuracy Verification of Manual 3D CG Reconstruction: Case Study of Destroyed Architectural Heritage, Bam Citadel

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Abstract. We explain our approach for verifying the accuracy of 3D CG manual modeling of the Citadel of Bam, which is an architectural heritage site destroyed by an earthquake in 2003. We attempted to control both the architectural quality of the 3D models with different methods and the technical 3D CG aspects since the 3D models of the Citadel of Bam need to be presented in a realistic virtual reality environment and also for research of buildings and spaces. Accuracy verification of 3D models was conducted through instructions and evaluation reports prepared by experts for modeling teams and different discussions between experts and 3D modelers.

Keywords: 3D CG reconstruction, 3D modeling, Evaluation, Quality Control, Cultural Heritage in Danger, Citadel of Bam.

1 Introduction

The Citadel of Bam is a huge complex of adobe architecture in the historical city of Bam in Iran. The city of Bam grew from the silk and cotton trade along the Silk Roads [2]. The Citadel is a collection of different architectural typologies with an historic Persian style in an area of around 180,000 square meters.

1.1 3D CG Reconstruction of Bam Citadel

The Citadel of Bam was destroyed in an earthquake in December 2003. The destruction was so severe, making physical reconstruction a great challenge. We proposed a faster and low-cost 3D Computer Graphics (CG) reconstruction, which could also help experts in the process of physical reconstruction. Since 2005, we have been constructing a three-dimensional model for a virtual reality (VR) presentation of the Citadel as part of the Digital Silk Road (DSR) Project of the National Institute of Informatics (NII) in Tokyo [1].

The most important areas, consisting of the most important buildings that were completely renovated before the earthquake, are being modeled manually [6]. For this

paper, we focused on the accuracy-verification process of the 3D modeling of the most importance areas, which we nearly completed [1].

1.2 Accuracy-Verification Process of 3D CG Reconstruction

It is evident that 3D CG reconstruction of a building must precisely replicate that building. However several limitations, such as destruction of the buildings and lack of precise and adequate documentations, make the ordinary approach of modeling a challenge. The Citadel of Bam suffered massive destruction and documentation on the Citadel before its destruction was scarce; therefore, the original shapes of many buildings cannot be recognized from 2D drawings, and complementary information should be derived from other heterogeneous data such as photos or sketches [3]. In many cases, it was necessary to make 3D models based on interpretation of relics [8].

The originality of shapes, the preciseness of proportions, the correct geometry of domes, vaults and arches of mud brick structures, and the high level of detail were some of the items we considered in the accuracy-verification process and quality control of 3D CG reconstruction the Citadel of Bam's buildings to ensure the quality of 3D models of the Citadel. This goal was not only to achieve an attractive virtual reality demonstration for attracting non-experts but also to support experts, particularly those involved in the physical reconstruction of the site, to do research, and analysis of the buildings and spaces of the 3D model

In the following sections, we explain three important accuracy-verification stages of the 3D CG reconstruction of the Citadel of Bam.

2 Management of 3D CG Teams

Our 3D CG teams are architectural students (from Espace Virtuel de conception en Architecture et Urbanisme (EVCAU), Ecole Nationale Supérieure d'Architecture Paris-Val de Seine (ENSAPVS)), with expertise in 3ds Max, computer graphics students (from the Global Information and Telecommunication Institute (GITI), Waseda University, Tokyo) with no knowledge of architecture, and professional 3D modellers (Razahang, University of Tehran, Iran). The 3D models made by each team must be merged in a unified final model. The most important instructions given to the modelers by the management team are listed below.

2.1 Scale of 3D Models

The 3D models of the different teams must have the same scale; therefore, each team must choose metric system with similar units and scale as defined in the instructions.

2.2 Coordinates of Elements

The X, Y and Z coordinates of any element must be drawn in global UTM. For this reason, 3D modelers have to use 3D cartographic map of the area¹, which is a

¹ This Photogrammetric material was made available under the Irano-French 3D Cartographic Agreement on Bam (IFCA) and the Iranian National Cartographic Centre (NCC).

photogrammetric material reconstructed from aerial photos taken in 1994. This map is a wire frame 3D model developed using Micro Station. It can be imported as an AutoCAD file with the “dwg” extension and easily used in a 3ds Max environment.

2.3 Layer Naming

The 3D model of the most important areas of the Citadel of Bam consists of buildings with different architectural components. These components were constructed based on one or several heterogeneous data sources. The chosen 3D modelling tool neither supports the design of an advanced schema with a hierarchy of classes, attributes of classes, and instances (like ontology schemas) [1] nor proposes a standard way of naming layers or components. Hence, we devised a simple methodology similar to linguistic morphology by defining affixes to name different layers as a single string.

With our layer naming system it is possible to display the name of buildings and recognize the reference data that the 3D model is built. Also, each model can be separated into its corresponding components that help us to easier and faster analyze, represent, and control. With the ability to hide and unhide layers, we can see and study building components separately or together. Each layer name consists of three parts in our models: a prefix to name the building, an infix to indicate the type of resources that have been used for 3D modeling, and a suffix to specify the type of architectural component forming the building, as shown in Table 1 [1].

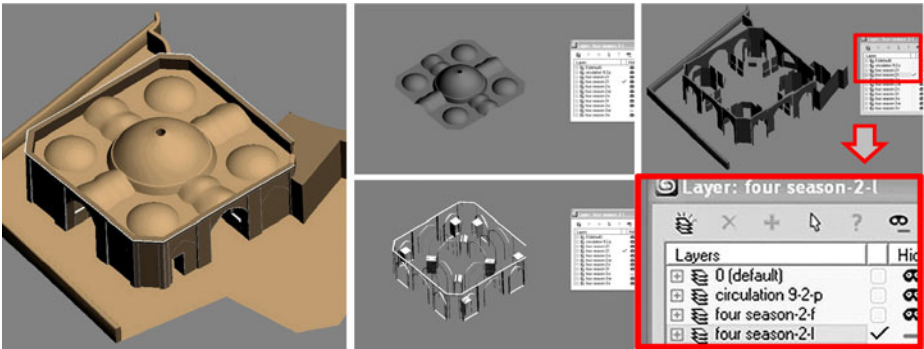


Fig. 1. 3D model and its components under layer naming

With help of this kind of layer naming, the 3D models of the different teams can be merged without changing or mixing the layers. The layers are listed in alphabetical order and can be used very easy in a highly complex model with many buildings and constructional elements.

To unify the heterogeneous data in the second phase of 3D modeling, a preliminary AutoCAD 3D model was developed. This data could be imported into a 3ds Max environment for completion. In these cases, the layer naming was created in AutoCAD and imported directly into 3ds Max.

Table 1. Layer management abbreviations for development of 3D models

Type of Layer Name	Abbreviation	Full Name	Description
Prefix		bazaar, mosque, ...	name of building identifying its function
		"vague"	The building doesn't have a name, there is a lack of data on the building, or the building is small or less important
		circulation	The component is part of a circulation element like a street.
		topography	topography of ground
		landscape	green spaces and natural scenery
		wall	city or defensive walls
Infix		1	imprecise maps
		2	precise maps
		3	photos
		4	sketches by skilled experts
		5	maps of similar style
		6	laser scan
		7	3D cartography maps
Suffix	r, l, f, w, d	roof, wall, floor, window, door	Following a number in case the component is numerous
	t	topography	topography inside the area of the building
	o	ornament	
	g	green space	small gardens inside the houses
	Suffix+ i	interior component	component below the ceiling of a closed space
	Suffix+ e	exterior component	

3 Architectural Quality Control

The 3D models of the Citadel of Bam are being developed in two phases. The data used by the 3D modelers and the quality of their work were completely different in these two phases.

3.1 First Phase of 3D CG Modeling and Problems

The first phase of developing the 3D models, from 2005 to 2007, revealed problems related to simultaneous use of heterogeneous data by 3D modelers [1], [4]. The most important problem for modeling teams in the first phase of the project was proper comprehension of the architectural data and the shortage of domain knowledge about traditional adobe constructions. Therefore at each period of completing the 3D models, architectural experts in the managing team of the DSR evaluated the architectural quality of the models and verified errors, and prepared a report. The reported errors should be corrected by modifying or remodeling the target building. The accuracy-verification process of the 3D models and error correction was repeated until every

problem was solved and the accuracy of the 3D model was evident. Most of architectural problems are discussed below.

Geometrical Problems. Finding the original geometry of spaces and also adobe constructions in the Citadel of Bam was an important challenge for the 3D modelers. There are few spaces with 90 grade angle edges and almost there are no flat surfaces of building elements. Most edges are not sharp, and adjacent surfaces have soft joints. The wall surfaces are not exactly vertical and the lower sections are thick and the upper sections are thin. 2D drawings are not precise enough to represent these geometrical aspects; therefore, the 3D modelers had to use on-site photos taken before the earthquake. They needed to superimpose the plan on the 3D cartographic maps (provided by IFCA project headed by Prof. Dr. Adle) to correct errors

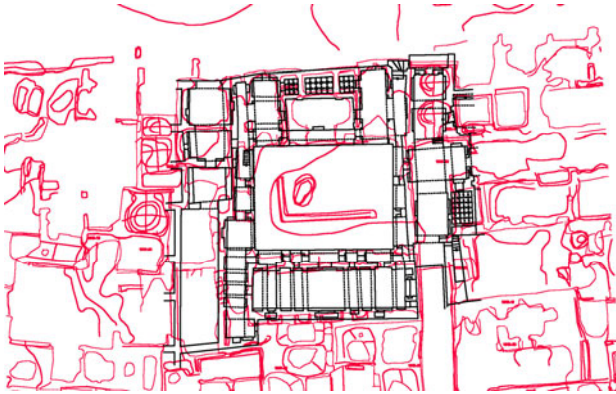


Fig. 2. Control of plan errors through superimposing with 3D cartography map, case of house of west of saabaat

Structural Problems. Due to destruction of most of the interior spaces and facades, modeling particular shapes of structural elements, such as arches, vaults, and domes, was a challenge.

Modelers needed to guess the type of element, such as a barrel or a cloister vault, by using aerial photos or some images from interior spaces and make the 3D model with accurate dimensions by using a limited number of 2D drawings and the 3D cartographic map (IFCA project). This process required domain expertise and was difficult for modelers.

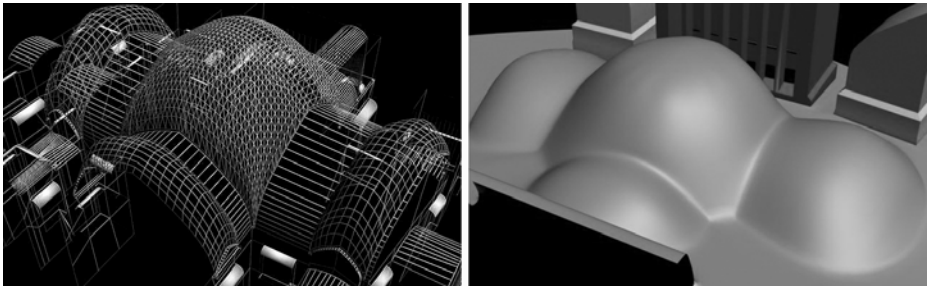


Fig. 3. Vaults in 3D model, the ceiling and the roof

Proportional Problems. The correct thickness, height, angle, and other dimensions of the buildings and spaces, the harmony between the inside and outside surfaces of architectural elements, and the correct position of elements combined are the main proportional aspects the 3D modellers must consider. By manually calibrating photos, the proportions of these building elements could be defined and used for 3D modeling. The 3D cartographic map (IFCA project) also helped to correct dimensions.

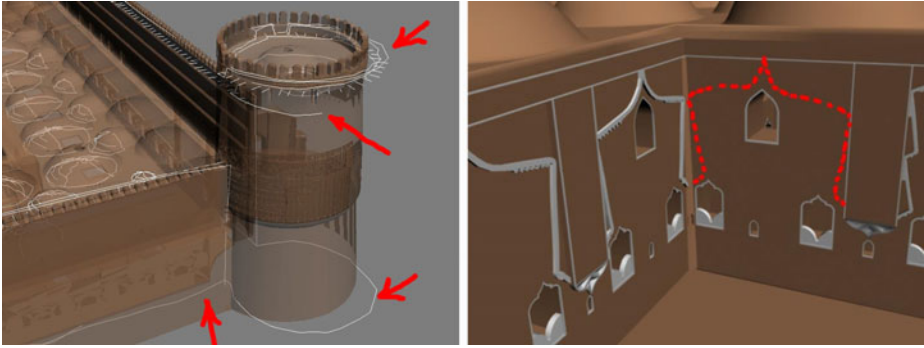


Fig. 4. Left: Difference between proportion of 3D model and 3D cartographic map (white lines), Right: ornaments that were not modeled (defined by red lines)

Detail Problems. Special details like chalk bands, ornaments like muqarnas and brickworks, combination elements of doors and windows, column edges, niches and arches were necessary for a highly detailed 3D model.

There were few high-resolution photos or 2D drawings precisely taken from these details, and 3D reconstruction was not possible for modelers without sketches or investigation and guidance from experts.

3.2 Second Phase of 3D CG Modeling and Problems

The modeling process in the first phase of the project was relatively slow and the models had several errors that had to be modified or remodelled. To overcome these problems in the second phase (since 2007), we prepared unified and precise data by combining all the heterogeneous data. These data consisted of information on the correct geometrical and structural character and correct proportions and details of the spaces and buildings. In particular, we developed an AutoCAD 3D wireframe model as a basic unified drawing of the Citadel. As we discussed in a previous publication [6], this model was prepared by complementary application of heterogeneous data and it can easily be imported into a 3ds Max environment and completed by 3D modellers who have little domain knowledge.

The architectural experts in the managing team developed unified data (3D wireframe model). Because of their familiarity with the content and chronology of the data and the original shapes of the mud brick buildings, the problems that were explained in the previous phase did not appear in the second phase. In the first phase, the tasks of the experts included controlling the correctness of 3D models, reporting errors or problems, and controlling the modification or remodeling process. This situation

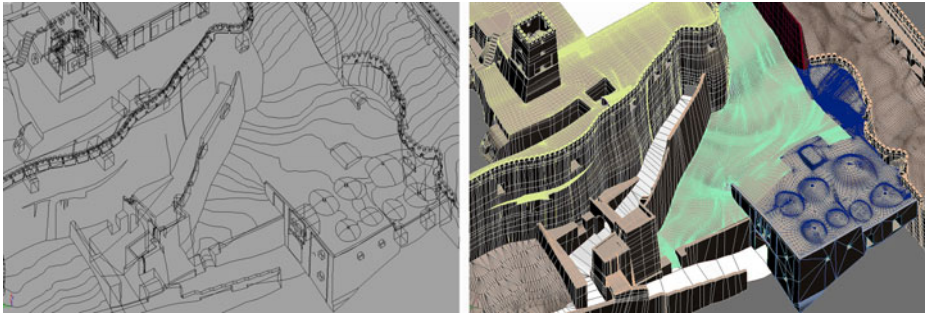


Fig. 5. Ramp and surrounding walls of Governor's Section in Bam Citadel drawn with help of wireframe model

required constant discussion between the modelers and architects, and the domain experts were overloaded with tasks. The 3D wireframe in the second phase decreased the dependency of modelers and domain experts and reduced the task load of both sides, which lead to easier and faster quality control by the experts and fewer remodeling and modifications by modelers.

4 3D CG Quality Control

Level of Detail. The 3D models of the Citadel of Bam are large and consist of several buildings, surrounding walls, topographies, and circulations. We need these models for VR presentation. The models can be seen from a normal distance (the nearest distance is around 25 cm) in a VR environment; therefore, we need to control the detail to an acceptable level. If we increase the number of polygons to more than what we need, the output 3D file will be very heavy, which will lead to over complexity and slow navigation, rendering, movement, and other presentation aspects when different buildings are combined. On the other hand, the number of polygons should not be decreased in such a way that the curved architectural elements lose their smoothness.

Appropriate Method of Surface Modeling. A realistic representation of the free form surfaces of an adobe construction of the Citadel of Bam is not easy and directly related to selection of the appropriate surface-modeling method for these elements inside the tool. For example Patch is appropriate for curved surfaces of buildings without complexity or parts that can be seen from a distance. NURBS is appropriate when a wire frame model of the space is available because the border lines of the architectural elements can be used for creating NURBS surfaces. Polygons are appropriate for surfaces with ornaments and complex curves, such as on roofs, that can be seen up close.

Interference or Incoherent parts. In the 3D models of the Citadel of Bam represented in the early stages of 3D modeling, there was interference, incoherence and forgotten surfaces, and parts that appeared due to inobservance. Seams between roofs and parapets, irregular lines between surfaces of vaults and chalk bands, intersection of roofs and ceilings, and incorrect intersections between windows and doors with walls were major 3D modeling errors reported for correction.

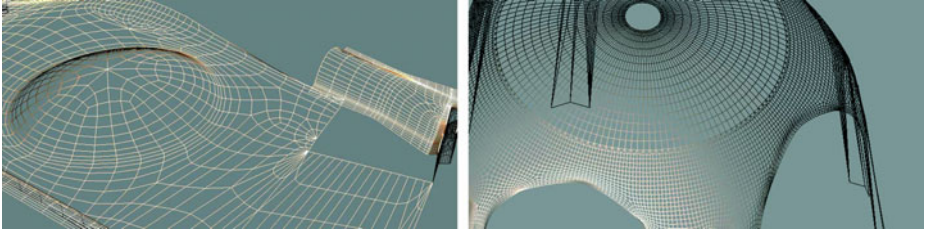


Fig. 6. Left: Example of exterior roof in Governor's House, Right: example of ceiling in Four Season building

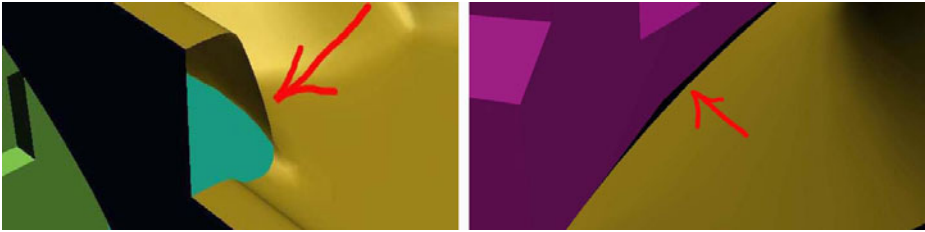


Fig. 7. Left: Example for forgotten surface, Right: example of two incoherence surfaces

5 Conclusion

We explained the accuracy-verification process of manual 3D CG modeling of heritage buildings, especially when such buildings have been destroyed and the documents for 3D CG reconstruction are incomplete or incorrect. In making the 3D CG reconstruction of the Citadel of Bam, we used three important accuracy-verification stages for achieving precise, reliable, and realistic 3D models based on the original constructions prior to destruction.

The first step focused on management between 3D modeling teams. Experts defined a guideline to harmonize the work of the teams and provided them a basis for coherent 3D modeling. The layer naming system is a key for coherent and semantic 3D modeling. The second step concerned the architectural aspects of the 3D models. We summarized all the architectural aspects of the 3D models in four groups: geometrical, structural, proportional, and details. The 3D modelers had to learn how they should use these architectural aspects after several accuracy-verification processes of 3D models by experts and correction of 3D CG errors. The third step concerned the technical aspects of 3D CG modeling.

Every error found in the three steps discussed above was specified and reported by taking snapshots of the 3D model, annotating the snapshots, and comparing them with photos or any other explanation to make them clear to the 3D modelers. The process of correcting the errors was observed carefully by experts to ensure the accuracy of the models.

This approach can be extended as a key process for large-scale high-precision manual 3D modeling, especially for projects that consist of different types of buildings with different 3D modeling teams in different places. For most of the archeological

sites where the original buildings were destroyed, proper application of heterogeneous information is key for precise 3D CG reconstruction. We discussed how each piece of information is applied and how it is modified or completed using other data. We proposed a management strategy in both phases of our project to provide an opportunity for different groups of modelers to work coherently and with fewer errors.

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Complementary Approach for Vernacular Wooden Frame Structures Reconstruction

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Abstract. The research is focused on traditional timber frame structures (TFS) situated in rural areas. Often neglected, remaining examples embody our build Heritage. However, architects have few tools to manage a conservation project in respect to the structural authenticity of these constructions. Therefore, providing a complementary tool able to automatically recognize and reconstruct traditional rural timber walling which have been structurally transformed is the major function of our research. The tool should automate as much as possible the procedure in two steps. Firstly, record the available examples of gables and identify their typologies. Secondly, formulate transformations hypothesis of a given wooden structure through time. The recording procedure is made by analyzing pictures with image processing in order to extract the wooden structures from colored pictures. The typology recognition is based on a statistical approach where' as structural approach will help to achieve reconstruction hypothesis. Structure recording and typology recognition will be presented in this paper.

Keywords: Timber framed structures, Conservation, Image processing, Features extraction, Reconstruction.

1 Introduction

1.1 Motivation

Studies and researches are more and more focused on reconstruction of ancient or vernacular architecture in a digital environment. This interest may be certainly explained by the progressive loss of our rural built heritage. For several authors (Pesez, 1983; Laslett, 2004), timber walling can be seen as part of a world we have definitely lost. However, if we pay more attention to our build environment, it can be argued that European countryside's still present several examples of vernacular wooden constructions. The reasons are various and can be resumed in three main points. Firstly, rural buildings were seldom assigned to respect town-planning laws which, for example, prescribed fireproof materials for the roofs and façades. Secondly, compared to rural areas, we can assume that the city houses have been much more transformed over ages. Finally, constructions localized in the countryside benefit from their geographical isolation. All these facts helped to preserve some vernacular buildings from disappearance until now. Nevertheless, this kind of architecture is fragile and hardly

resists to carelessness of the owners. In a restricted area, vernacular constructions often show similarities to each others due to construction habits of their creators who reproduced a particular existing canvas based on their experience and culture. However, if the constructions still exist, structures may have been strongly transformed to respond to social and economical needs. As a result, despite a global homogeneity of their architecture, each house has something particular in its construction which explains the adjustment of the traditional way of building applied to a particular context. From our concern, we assume that the particularities also reflect more structural transformations/adaptations rather than ornamentations of the façades. We assume that socio and economical context, functional and dimensional requirements are main factors which influence the wooden frame structures design. The influence of the socio and economical context is expressed in the various typologies expressions which reflect a regional belief, the construction style of a carpenter or a lack of particular building materials. In the regions where wood is easily available, timber-framed houses are made of larger beams. At the opposite in the farming regions, constructions have been developed to spare wood as much as possible. As a consequence, structures are often more complicated, using shorter span. Often, constructions have been also transformed due to laws which have forbidden flammable materials such as thatch which obliged to modify the slope of the roof to be adapted to slate.

In several countries such as Belgium, theoretical studies have been published on traditional wooden architecture (Genicot, 1989; Genicot & Butil, 1996; Hoffsummer, 2002; Houbrechts, 2008). Past studies identified that these transformations are more visible in the gable structures. Since the researches carried out in the 90's, it is assumed that timber-framed gables are particularly expressive and distinguishable into typologies according to the architecture and design characteristics of their structures. In the French-speaking part of Belgium, five typologies have been roughly localized taking into account that an exact division of regions is impossible due to intercultural influence between neighbouring regions (fig. 1).

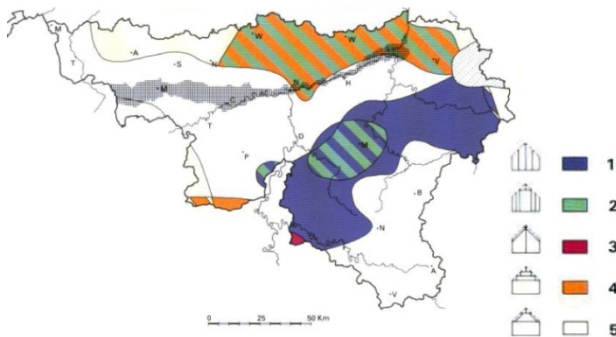


Fig. 1. Localisation of (TFS) in south Belgium by Genicot

This mapping has been used as a reference in order to classify pictures of remaining examples. Type 1: king post and posts rising from a timber sill to the edge, type 2: posts rising from a timber sill to the edge with a rail in the upper part of the gable,

type 3: wall plate supporting two posts with a rail in between, type 4: tie-beam and collar-beam supported by braces, type 5: king post rising from a timber sill to the ridge (fig. 2). The richness, the variety but also the fragility of these structures justify to provide to the architects and historians a way to evaluate their quality.

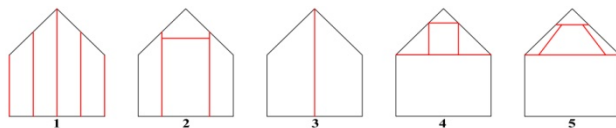


Fig. 2. Referenced gable structures from fig. 1

1.2 Aims

The study has two aims. Generate an automatic tool which firstly, record the available examples of gables and identify their typologies. Secondly, formulate transformations hypothesis of a given wooden structure through time. The recording procedure is made by analyzing pictures with image processing in order to extract the wooden structures from pictures. The typology recognition of the structures is based on a statistical approach. Reconstruction hypothesis are based on shape grammar analysis.

2 Methodology

2.1 Wooden Structure Extraction

The acquisition of data has to be straightforward, avoiding special computing knowledge of the user. An orthophoto of a gable is required for the processing. In order to record, compare and reconstruct the hypothetical structures, we first need to extract the relevant information from the photography. The ability we have to visually isolate the different parts of the image is due to our knowledge of materials and perception of colors (Tucker & Ostwald, 2007). In our context, everyone is able to easily distinguish the wooden parts of the structures at first glance because we all know how wood looks like. The major difficulty in an automatic feature extraction process is to characterize the wooden material to be extracted. Thresholding techniques have been applied. Basically, thresholding methods turn all pixels below some threshold to zero and all pixels over that threshold to one. As a result, we get binary images from the grey-level ones (figure 3).



Fig. 3. Thresholded picture. Type 1 example. (RGB/gray/level/BW).

However, using gray levels pictures never provided satisfactory results for the wooden beams extractions. Therefore, in our research, features extractions of the wooden structures have been based on chromatic peculiarities. For this reason, RGB colored pictures has been used for the thresholding. Because we want to compare some existing drawings from past surveys, we decided to extract the edges of the beams from the thresholded image. As a result, these representations can be compared with drawings of existing or even disappeared buildings.

2.2 Typology Recognition

The statistical approach aims to express the different structures examples by means of numerical parameters coming from their Euclidian (length, width) dimensions. In addition, the concept of fractal geometry is used to express the visual complexity of the gable structures in order to calculate for each example, a number called its fractal dimension. Fractal geometry has been exposed in the 80's by Benoit Mandelbrot (Mandelbrot, 1983). Literally, the word fractal, coming from Latin *fractus* means "broken". Therefore, a fractal form is fragmented, geometrically torn, divided into parts from which each is approximately a smaller copy of the whole. In architecture, when we look closer and closer to a building façade, this never ending progression of self similar parts is never infinitely refineable. However, some forms and details can be reproduced from large to small scales. In 1995, Carl Bovill developed these concepts and proved it was possible to express the visual complexity of an architectural conception by calculating a number called its fractal dimension which measures the mix between order and surprise (Bovill, 1995). Fractal geometry in architectural composition is related to the formal study of the progression of interesting forms, from the distant view of the façade to intimate details. As Bovill mentioned rural architecture shows natural detail progression from a large to a small scale. These details can be expressed by ornaments or complexity resulting from the structures. Therefore, from this point of view, all architecture is fractal at certain scales. However, if the fractal dimension of an object refers to the visual complexity of its structure it cannot be related to its esthetical value. In order to calculate the fractal dimension of objects, Bovill proposed the box-counting method.

The method applies an iterative procedure:

- Superimpose a range of different scale grids ($s1$, $s2$) over the picture you want to study ($s1$ is the first grid size).
- Count the number of boxes $N(s1)$ that overlay parts of the image.
- Repeat the procedure, changing $s1$ to $s2$ with $s1 < s2$. The number of boxes containing details of the picture will change with the grid size (fig. 4).

As a result it is possible to obtain a log-log linear correlation between the number of boxes counted and the associated size of the grid. The slope of the regression line is an estimation of the fractal dimension D_b of the picture (fig. 5). $N(s)$ is the number of boxes in each box grid which contains part of the structure and $1/s$ is the number of boxes across the bottom of the grid.

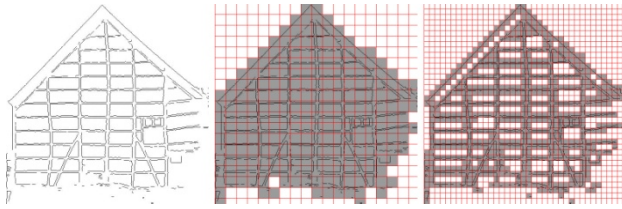


Fig. 4. Applying box-counting method to gable structures

$$D_b = \frac{[\log(N(s_2)) - \log(N(s_1))]}{\left[\log\left(N\left(\frac{1}{s_2}\right)\right) - \log\left(N\left(\frac{1}{s_1}\right)\right) \right]} \quad (1)$$

Fig. 5. Box-counting dimension D_b formula

High fractal dimensions ($D_b > 1.5$) mean high visual complexity. As it has been illustrated (Lorenz, 2002; Zarnowiecka, 1998), box-counting method can be used to measure the visual complexity of a vernacular features. Consequently we believe it can highlight an architectural transformation of its structure. Studies proved that box-counting method is also an effective way to evaluate the complexity of our environment (Tucker, Ostwald, Chalup, Marshall, 2005) or artifacts (Elizondo, 2001). It has been proved that ornament subdivides building facades on many different scales and the most effective hierarchical scaling creates a fractal geometry (Moughtin, Tanner, Tiesdell, 1999; Salingaros, 1999).

2.3 Structural Reconstruction

The structural approach is often used when the patterns have a definite structure which can be expressed in terms of composition rules of the form $A \rightarrow B$ (Stiny, 1980), where A and B are shapes made up of solids, planes, lines or points. The patterns are viewed as being composed of simpler subpatterns which are themselves composed of simplest elements. As a consequence, if a set of rules is able to express the generation of a kind of form, then it is possible generate new forms based on the language which has been created (Colakoglu, 2005; Cagdas, 1996; Flemming, 1987). Therefore, each typology has been expressed through several rules of construction. The combination of these rules allows generating existing examples of wooden frame structures as well as disappeared or still unrecorded structures. The rules parametrization is compulsory in order to avoid absurd reconstruction. A decision tree based on statistical observation is used to guide the user. For each region, width and height of the façades as well as the ratio (W/H), the slope of the roofs, the dimensions of the panels, height of the bases are parameters which help to restrict and improve the reconstruction. As a matter of fact, the panel dimensions are related to the gable dimensions which are themselves linked to the geographical area.

3 Results

3.1 Image Processing

Images processing has been mainly achieved with Matlab. In a picture, a construction is never isolated from its backgrounds. Often, vegetation, artifacts or other constructions have to be removed from the photography. As shown in fig.3, segmentation using grayscale pictures did not give satisfactory results. We decided to work on RGB pictures by using the algorithm “find_color” developed by Ikaro Silva on Matlab. Several other steps have been also added to this algorithm in order to be more adapted to the contexts. Working on colored pictures, the algorithm successively extracts the pixels which have the same color and turn them to black. Then, the boundaries of the structure can be extracted (figure 6).



Fig. 6. Segmented picture (RGB/segmentation/edges)

3.2 Pattern Recognition

12 pictures and 34 drawings founded in the literature have been analyzed. All are 1:200 scale representations. Keeping the same scale representation is compulsory if we want to compare the fractal dimensions of the various gables analyzed within a same range of different scale grids. Two typologies are presented in this paper (type 1 & type 4). Both are divided in two groups: intact and transformed structures. Each typology has been distinguished in two groups in order to identify the original structures (1_{original} and 4_{original}) and the structures which have been transformed through time ($1_{\text{transformed}}$ and $4_{\text{transformed}}$). The results conclude that original structures are rather represented by extreme values of the ratio (width/height). Structures of type 1 have rather high ratio expressing their squatness. At the opposite, structures of type 4 are rather slender. On the other hand, transformed structures can be identified by an extreme value of their fractal dimension (D), expressing that structures of the type $1_{\text{transformed}}$ are mainly more complex than type $4_{\text{transformed}}$ (figure 7).

The number of studied examples is of course relevant if we want to achieve statistical recognition. That is the reason why the data base must be enlarged. However, lots of gables have been hidden under a cladding or even included in new constructions. In some cases, artifacts do not allow access. In order to quickly enlarge our data base, we also propose to use a two-dimensional shape grammar able to generate existing but also unreferenced structures. This knowledge-based approach must help to design wooden constructions that satisfy formal and structural observations.

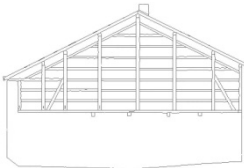
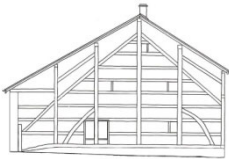
Type 1	
Intact structures (1_{original})	Modified structures ($1_{\text{transformed}}$)
	
Mean val (W/H) for the group =1.58 Mean val (W/H) overall =1.38	Mean val D for the group =1.42 Mean val D overall =1.38

Fig. 7. Statistical results for type 1

3.3 Reconstruction Hypothesis

The parametric rules aim to create idealized two-dimensional representations of typologies structures. At first, it is necessary to analyze the typologies particularities in order to generate a vocabulary able to explain the structural language of the wooden gables. Then, the language has to be transformed into a shape grammar capable of proposing existing or innovative designs.

The language of the timber-framed houses is defined by the beam layouts inscribed within the gable geometries. The vocabulary elements in the shape grammar are an initial shape with constrained parameters. Five simplistic typologies are used to characterize each gable structures. At first, the gable envelope and its base are generated. Then, the façade is transformed by successive rules which (re)construct the intact wooden structure (figure 8). Depending on statistics coming from case studies, several reconstruction possibilities are proposed to the user (figure 9).

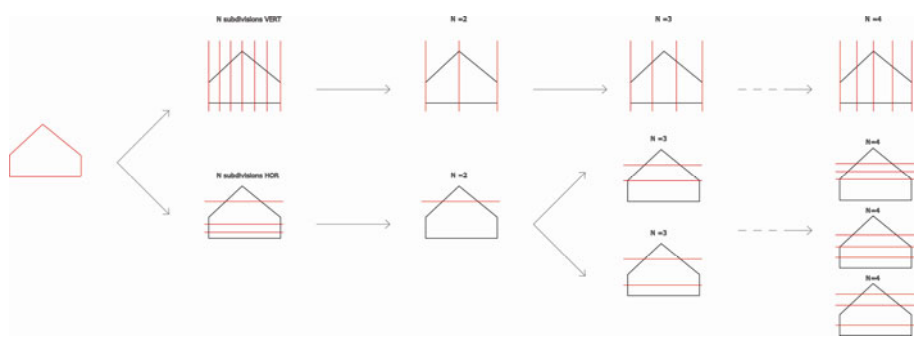


Fig. 8. Iterative rules for type 1 and type 4 reconstruction

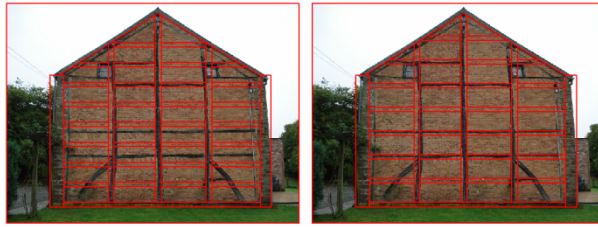


Fig. 9. Incorrect (left) and correct (right) reconstruction of a gable

4 Conclusions

Traditional timber frame structures embody particular ways of building. These particularities are illustrated by means of different structural typologies geographically localized.

In this paper, a method able to make architectural recognition of wooden frame structures has been illustrated. It constitutes a work in progress. A statistical approach is based on geometric concerns as well as the evaluation of the visual complexity of wooden frame structures. First results proved that intact and transformed structures examples can be distinguished within the same typology. These first conclusions must be considered with caution due to the little amount of examples. Nevertheless, fractal dimension and geometrical proportions (W/H) have proved to be relevant for vernacular wooden structures distinction. Despite few examples, the statistical approach shows encouraging results. An extended data base should confirm and refine the actual results. A shape grammar adapted to traditional timber framed structures is developed. Wooden constructions seem particularly adapted to this kind of analysis. The creation of existing and unknown structures based on generated rules is a way of studying architecture styles, particularly if the represented examples are difficult to survey. These two approaches will be used as a basis to develop a reconstruction methodology.

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CARARE: Connecting Archaeology and Architecture in Europeana

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Abstract. CARARE is a best practice network funded by the European Commission's ICT Policy Support Programme. The network brings together heritage agencies, organisations, archaeological museums, research institutions and specialist digital archives to establish a service that will make digital content for Europe's unique archaeological monuments and historic sites interoperable with Europeana. As well as bringing 2D images and text documents to Europeana, CARARE will bring a mass of geo-referenced content to Europeana and adds 3D and Virtual Reality as new content types. This paper looks at the activities of the CARARE project in establishing and aggregation service for the archaeology/architecture domain including work to mediate the rich metadata held by the domain for presentation in the Europeana Data Model, the use of semantic web technologies such as SKOS, and work on the documentation and preparation of 3D and VR content for online publication and discovery via the Europeana search service.

Keywords: CARARE, Europeana, Archaeology, Architecture, Heritage Data.

1 Introduction

CARARE is a Best Practice Network, funded under the European Commission's ICT Policy Support Programme, which started on 1 February 2010 and will run for three years. It is designed to involve and support Europe's network of heritage agencies and organisations, archaeological museums and research institutions and specialist digital archives in making the digital content for the archaeology and architectural heritage that they hold available through Europeana, and will establish an aggregation service for the archaeology/architecture heritage domain. CARARE is one of a suite of projects which have been funded by the European Commission to help develop Europeana, and builds on the work of earlier projects which have helped to establish a framework for interoperability within the domain.

1.1 Background and Related Work

From the 1980s there has been work at international level to establish core standards for inventories of historic buildings, archaeological sites and cultural landscapes with

the aim of improving their management through inclusion in planning and sustainable development processes. The Core Data Index to Historic Buildings and Monuments of the Architectural Heritage established by the Council of Europe was rapidly followed by the CIDOC Core Data Standard for Archaeological Sites and Monuments [1][2]. These standards have been implemented in information systems by heritage agencies across Europe to fulfil the obligations of the Granada and Valletta conventions [3][4] and thus providing a starting point for interoperability and information access. The establishment of the European Heritage network (HEREIN) by the Council of Europe has played an important role in promoting the exchange of information on heritage policies across Europe also contributing to the development of multilingual terminology resources [5].

Two projects have been important in terms of their work on interoperable portals for the cultural heritage and multilingual terminology. *AQUARELLE* (1996-1999) was funded by the European Commission's telematics programme to demonstrate resource discovery across distributed data sources from the museums and heritage domain; it also developed a multilingual thesaurus server to enable user browsing. [6] [7]. *ARENA* (2000-2004) was funded by the Culture 2000 programme project to digitise archaeological archives from six countries and make them accessible to users via the *ARENA* portal. The *ARENA* project has been described as a "path finding" project which set out to investigate and demonstrate the reality of using ICT to enable archaeologists to communicate and share data throughout Europe [8][9][10].

More recently *DARIAH* (Digital Research Infrastructure for the Arts and Humanities) has been funded by the European Commission's FP7 programme to investigate, develop and maintain infrastructure to support ICT-based research practices across the humanities and arts. In its preparatory phase the project is building on work by the earlier *ATHENA* project to provide a demonstrator of service oriented architecture enabling access to electronic archives [11].

The *EPOCH* Network of Excellence, funded through the EC's Sixth Framework programme focussed on the development of open source tools and service to support 3D visualisations and the flows of information from archaeological discovery to education and dissemination [12]. Of particular relevance to *CARARE* are the open source tools such as *ARC 3D*, *MeshLab*, *CityEngine* and *InMan* which have become available to cultural institutions to use in the 3D visualisation and interpretation of historic buildings, archaeological monuments and landscapes as a result of the project. *SCULPTEUR*, an earlier project supported by the EC's 5th framework programme is also of interest for its work demonstrating the potential to navigate, search and retrieving 2D images and 3D models using a combination of metadata and content-based searching.

1.2 Cultural Heritage without Borders

These projects and others (such as the *Pathways to Cultural Landscapes* Project [13]) illustrate the desire amongst researchers and heritage professionals for cooperation across national borders and to embrace the possibilities offered by information technology to improve search and discovery of digital content.

Europe has a common cultural heritage in which present national borders have little relevance for "cultures" through prehistory and early historic periods. There has

been a long-term ambition amongst archaeologists of sharing heritage information across borders through interoperable information systems able to query data from several nations at once and present the result in a meaningful way to users. The potential for cross-border research was discussed by Dam and Hansen in their review of the Arena project [14].

This ambition is very much in line with the initiative to establish Europeana as a single point of access to Europe's cultural heritage and makes entry to Europeana a logical next step for heritage information.

2 Introduction to CARARE

CARARE has been established as a Best Practice Network with funding through the European Commission's ICT Policy Support Programme to involve Europe's network of heritage agencies and organisations, archaeological museums and research institutions and specialist digital archives in the Europeana initiative.



Fig. 1. CARARE project logo [15] © CARARE 2010

The project started on 1 February 2010 and will run for three years. It is designed to:

- Support its member organisations in making the digital content for the archaeology and architectural heritage that they hold available through Europeana,
- aggregate content and deliver services,
- and enable access to 2D, 3D and Virtual Reality content for heritage objects for the users of Europeana.

2.1 Archaeology and Architecture in Europeana

The major objective of CARARE is to increase the quantity and quality of digital content for the archaeological and architectural heritage that is available to users of Europeana. Such content is particularly relevant to Europeana having great potential to support services for cultural tourism and users with interests in local history, family history and humanities research.

Analysis of the content of Europeana in summer 2009, following the initial ingest of 5 million items to support the launch of the prototype service, concluded that there was a need and demand to increase the available content for the archaeological and architectural heritage.

CARARE proposes to meet this demand by enabling an estimated 2 million items for 1 million unique monuments, buildings, landscapes and heritage sites to be included in Europeana. Including content from heritage organisations in Europeana alongside material from museums, libraries, archives and audio-visual collections will enable sources to be brought together and researched in ways that have rarely been possible previously. It will become possible to bring together distributed collections which have been scattered as a result of long ago boundary changes or the activities of different researchers and institutions.

2.2 Adding a New Dimension to Europeana: 3D and VR

In addition to bringing 2D images and text material to Europeana, CARARE will have a special focus on the 3D and virtual reality models created by archaeologists and architectural historians to record, analyse and present heritage sites and objects. The project aims to solve issues concerning the harvesting and presentation of these formats for Europeana and for other domains.

One issue that is particular to 3D is that users are often required to install browser plug-ins in order to view 3D content. As 3D formats and viewers are relatively unstandardized there is a risk that Europeana users could be directed to install many different plug-ins, this is particularly the case as it is intended that the 3D content will remain on the original content provider's web-servers. To simplify matters for Europeana users, CARARE will make recommendations to content providers on best practices including a set of visualisation technologies for Europeana which are multi-platform, multi-browser and (if possible) do not require the installation of plug-ins.

2.3 Place and Geographic Information

CARARE will also make a positive contribution to Europeana by bringing a critical mass of content which includes spatial coordinates as well as place names, and also the expertise of the heritage community in working with geographic information and geographic information retrieval.

The work by CIDOC and the Council of Europe in establishing Core Index data for monuments and historic buildings included specifications for place information. This work provided the starting point for the widespread implementation of GIS by heritage agencies as technologies became available. Place is one of the most frequent starting points for enquiries about the archaeology and architectural heritage of an area. Importantly the inclusion of spatial coordinates in

record sets enables archaeology and architecture data sets to be included in geo-portals alongside other datasets used in planning, development control, tourism and other map-based services.

Differing map projections, coordinate systems and standards cause issues when bringing together spatial data sets from different regions. The 2007 INSPIRE Directive seeks to solve this issue for environmental datasets by establishing an Infrastructure for Spatial Information in the European Community [16]. Many heritage agencies are currently working towards implementing the INSPIRE directive and this is an area where CARARE can contribute expertise to Europeana.

3 Content

CARARE is contributing to the expansion of Europeana both in terms of involving new content providers from the archaeology/architecture domain in Europe and in terms of the content being made accessible. More than 2 million digital objects have been identified in the initial survey by partners. The actual content that these partners will make available to Europeana via CARARE includes:

- archive items created by local citizens, visitors, scholars and scientists who have explored, described and depicted heritage sites since the earliest times, and
- photographs, measurements, drawings, reports, plans, maps, 3D and virtual reality models created by heritage agencies in support of their mission to manage and promote understanding of the heritage sites within their area.

3.1 3D, Virtual Reality and Virtual Reconstructions

3D and virtual reality models are increasingly used in the archaeology/architecture domain to record, analyse and present complex monuments and buildings (see figure 2). The initial content to be made available through CARARE includes 3D and virtual reality models of sites that are of high heritage interest at international, European, national and local level and includes:

- 3D model of the Pompeii civic forum
- Virtual reality model of Ta' Hagra Temple, Malta
- 3D scan of the fortifications at Gdańsk, Poland
- SVG plan of Silchester Roman town, UK
- 3D models and virtual reality reconstructions of the Paphos theatre, Cyprus and also
- 3D models of ceramic vessels

This content type is not yet represented in Europeana. The initial focus in establishing the Europeana Service was on building a critical mass of textual and image based content with moving image and audio content being added more recently through projects such as the European Film Gateway, EU Screen and Europeana Connect. The first prototype of the Europeana service (www.europeana.eu) was designed around four major content types: images, text, audio, moving image. One of CARARE's activities will be to define the functional specifications to establish both the workflow and a new search facet for 3D and VR content.



Fig. 2. Middle Byzantine Church, 1200 A.D., Episkopi Manis, Hellas © The Ministry of Culture and Tourism - 5th Eforate of Byzantine and Post-Byzantine Antiquities (3D Digitization by CETI, Athena Research Centre)

4 Metadata

CARARE will establish an aggregation service for archaeology/architecture organisations. This service will harvest metadata from its content providers, providing data mapping tools to enable the metadata to be transformed into Europeana friendly formats. This transformed metadata will in turn be made available by the CARARE service for harvesting and ingest by Europeana. The aim is to provide the necessary guidance, standards and infrastructure to establish a channel which improves the interoperability of digital content from the archaeology/ architecture domain with Europeana.

4.1 Achieving Semantic Interoperability

Achieving syntactic and semantic interoperability across the metadata sets and the different media formats that exist in heritage organisations is the largest challenge for CARARE. To achieve interoperability between the different native metadata formats, CARARE is exploring the use of the CIDOC CRM to mediate between the semantics of the original data and the standards and schemas defined by Europeana.

The CIDOC CRM (Conceptual Reference Model) represents an 'ontology' for cultural heritage information and describes in a formal language both explicit and implicit concepts and relations which are relevant to the documentation of cultural heritage. The CRM provides the basis for mediating cultural heritage information and the semantic "glue" needed to transform local information sources into coherent global resources [17].

4.2 Mapping and Transformation

CARARE will ask its content providers to map their native metadata schema to an implementation of the CIDOC CRM which will in turn be mapped to the Europeana

Data Model (EDM) [18]. This approach provides flexibility, allowing for development both by Europeana in its data model and the metadata that it maintains to support the main function of search and discovery and also allowing for the maintenance and development by content providers of richer descriptions of heritage objects.

An early decision for CARARE has been selecting an implementation of the CIDOC CRM for use in the mapping tool which will be made available to CARARE content providers. Both RDF and XML implementations of the CRM have been made available and are published on the CIDOC website. Early discussions with CARARE content providers revealed that there were barriers to the implementation of the full RDF schema which would increase the training requirement for heritage professionals who would be undertaking the data mapping. XML implementations of the CRM were found to be more user friendly and to offer the potential for customization for the heritage domain.

4.3 MIDAS Heritage

MIDAS Heritage is a data standard for information about the historic environment which was developed for use in the UK and Ireland and is maintained by the Forum on Information Standards in Heritage [19]. MIDAS builds upon the following sources:

- The development of international data standards for the cultural heritage sector, including the Core Data schemes for historic buildings and archaeological monuments and the CIDOC CRM;
- A first edition of the MIDAS standard [20];
- The experience of the members of the Forum on Information Standards in Heritage in its application (FISH).

MIDAS covers three major areas:

- the individual assets that form the historic environment (buildings, archaeological sites, shipwrecks, archaeological areas of interest and artefacts);
- the work that is undertaken to understand, protect and manage change to those assets (events);
- sources of further information (archives).

In addition to the published documentation, presentations and training materials available for the MIDAS standard, the Forum on Information Standards in Heritage has developed an interoperability toolkit to assist in the process of moving information between information systems with funding from English Heritage and the National Trust [21]. The tools include:

- MIDAS XML
- INSCRIPTION controlled vocabulary and identifiers
- Tools to validate the contents of MIDAS XML files.
- Historic Environment Exchange Protocol (HEEP), a web service protocol to standardise remote querying on heritage data

After a review of the MIDAS heritage standard alongside other implementations of the CIDOC CRM and the CRM itself, CARARE concluded that the standard was of interest for use in the project. The fact that MIDAS builds on the work by CIDOC and the Council of Europe on Core Data for archaeology and architecture gives the schema a European relevance as it covers concepts that are familiar to most heritage agencies in Europe that maintain monument inventories. Mapping between MIDAS and the CIDOC CRM also facilitates its use by CARARE as a schema to mediate between the native metadata held by CARARE partners and the Europeana Data Model.

English Heritage are now working with the CARARE project to internationalise MIDAS, which includes updating the standard to conform to the INSPIRE directive on geographic information.

4.4 Europeana Data Models

Europeana has developed metadata specifications to support the functionality of its search portal and interoperability with the numerous metadata schemes in use by its content providers. The Europeana Semantic Elements (ESE) was published in summer 2008 to support the first prototype portal [22]. There have been minor revisions to the ESE schema since its first publication and it will continue to be used in the new release of the Europeana portal due in summer 2010. But the Europeana v1.0 project has been working on the Europeana Data Model (EDM), based on Semantic Web principles, to enable additional functionality to be incorporated in future releases of the Europeana portal due in summer 2011.

The ESE schema was based on Dublin Core Metadata and, while it supported item level retrieval in the first Europeana prototype portal well, it did not differentiate between temporal and spatial coverage sufficiently well for the archaeological or architectural heritage. The EDM schema is a semantically richer schema which takes into account concepts from the CIDOC CRM and in making clear distinctions between the concepts of time-span, place, agents and events (see figure 3) is more suited to archaeological and architectural heritage objects. For this reason the CARARE project has elected to provide data to the 2011 Europeana release in EDM format.

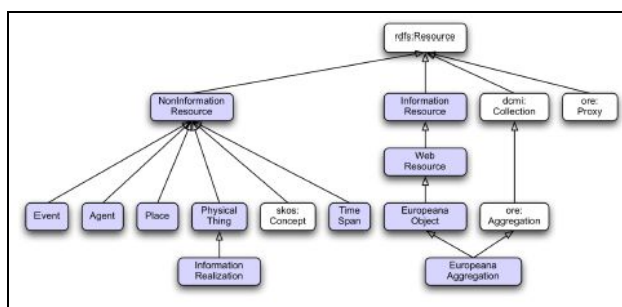


Fig. 3. The EDM class hierarchy © Europeana 2010

An important development in the current version of the EDM is its re-use of concepts from ORE, RDF and SKOS opening the potential for exploitation of semantic web technologies. CARARE plans to benefit from these capabilities and is looking at the SKOSification of multilingual terminology resources for the heritage and at the potential for establishing linked data for use within the domain.

5 Harvesting and Aggregation

Europeana is based on a distributed architecture with aggregation services such as CARARE harvesting and aggregating metadata from content providers and then being targeted for harvesting Europeana itself.

CARARE will establish a network of repositories amongst its content providers which are interoperable with its harvester. The OAI-PMH communication protocol [23] is the preferred method for metadata delivery to CARARE although other web-services may be considered with individual content providers. From the perspective of content providers, the use of OAI-PMH has benefits as it can be implemented on many systems using Open Source software and is increasingly being implemented by vendors of repository systems. It is one of the key standards that have been promoted to culture sector stakeholders and the resultant availability of tools means that the barriers to entry for stakeholders, especially those who are creating new repositories, are relatively low.

5.1 CARARE Workflow

To enable the aggregation of quality metadata into Europeana, CARARE is implementing an ingestion workflow, which centralises some processes in the CARARE repository and enables content providers to be involved in controlling the quality of the metadata produced for the Europeana environment. The stages of the workflow are as follows:

- 1) Metadata will be harvested from each content provider and to the CARARE repository where it will be indexed and stored in an XML data format. Content providers will be able to declare the harvest as either complete (new, updates or deletes) or partial (new or updated or mixed).
- 2) Content providers will complete a mapping of the data fields in their native metadata to CARARE's implementation of the CIDOC CRM, MIDAS Heritage using a web-based metadata mapping tool provided by the National Technical University of Athens for the CARARE project.
- 3) CARARE will complete a mapping of the CRM implementation to the Europeana Data Model (current version). It is important to note that the EDM schema is still evolving as new functionality and content types are identified for Europeana. By asking content providers to map their data to an intermediary schema (step 2) and then mapping this schema to the EDM, CARARE aims to avoid asking its content providers to do repeat mappings.
- 4) CARARE will convert selected multilingual thesauri identified by CARARE content providers to SKOS using automated tools.

- 5) Content providers will be able to view their metadata transformed in Europeana's format in a test environment to check and resolve any data issues which might include:
 - i) Refining the data mapping
 - ii) Mapping their terminology to selected lists
 - iii) Normalizing the data to Europeana standards, e.g. adding the language of the metadata, content type etc.
 - iv) Linking terms to SKOS thesauri
- 6) CARARE will run a quality control check, for example to check for any missing values or malformed data and report back on the content providers data.
- 7) Once the checks are completed validated Europeana metadata will be made available in the CARARE OAI-PMH repository for harvesting by Europeana. The SKOS thesauri created and used in CARARE will also be made available to Europeana.

CARARE's workflow is illustrated below in figure 4.

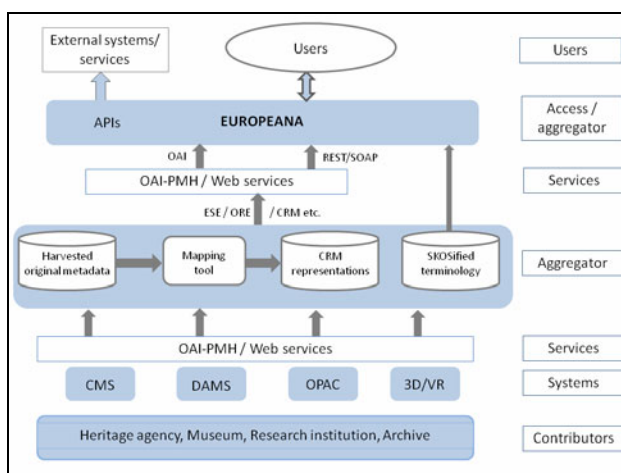


Fig. 4. CARARE's harvesting and aggregation service © CARARE 2010

6 3D Content

CARARE has a specific work package which is focussing on the issues around making 3D and VR content accessible to Europeana. The content survey will help to identify in more detail the formats that are held by CARARE content providers, initial feedback indicates that there is a wide range which includes simple models of museum objects, complex reconstructions of major archaeological sites, virtual tours, CAD data files (useful for students and professional users), and 3D models associated with large related 2D archives, with different levels of granularity and considerable variation in the metadata that is currently available.

The metadata needed to support the description, preservation and discovery of the 3D/VR models produced in the archaeology/architecture domain is one area that is under discussion. On a professional level it is important to document the methods and techniques used in capturing 3D models of real-world archaeological and architectural objects, and in creating virtual reconstructions of these sites as they appeared at various times in the past. Such information may be less immediately important to a general user of 3D models, who may rely on descriptions of the site, its associations and characteristics (who, what, when) and location for resource discovery, and on technical metadata describing the format of the model in order to view the model itself. CARARE is looking at these metadata requirements in order to make recommendations to its content providers and to Europeana.

Another aspect of the metadata for 3D which is under review is the relations between the parts of complex models (which may comprise of a series of linked 3D objects) and between 3D models and linked information sources. 3D and Virtual Reality models increasingly include links to external digital content such as text documents and images, which enhance their educational value. These complex relationships between objects and metadata also increase the complexity of ingesting 3D collections into a repository. The 3D-COFORM project, with funding from the European Commission's 7th Framework programme, is carrying out a programme of research in this field, looking in particular at 3D documentation and the deployment of affordable, practical and effective technologies for use in the cultural heritage sector [24]. At the technical level, it is helpful that 3D-COFORM is investigating the relationships between the CIDOC-CRM and METS as ontologies, provenance data encoding and standard geometric representations (X3D, Collada). CARARE is following the research activities of the 3D-COFORM project consortium with interest and will take its results into account when making practical recommendations to the archaeology/architecture community.

One more aspect of 3D which is under consideration in the CARARE project is the rendering of 3D models online for general users. 3D digitisation of large buildings or monuments often results in very large volumes of data and heavy-weight models, which are too large for presentation on the web. Such models may be made available off-line on standalone systems, or they may be converted (simplified) for presentation on the web. Current best practice guidance recommends the use of VRML, X3D and Collada as standardised formats with longevity [25] [26]. These are very good choices for digital preservation but viewing models in these formats still involves users in installing browser plug-ins, and as the plug-ins are not browser independent different plug-ins need to be offered by content providers. Embedding 3D models into PDF documents may offer a cross-platform solution that enables this content to be viewed without the need to install plug-ins. CARARE plans to make recommendations to Europeana content providers on the selection of suitable visualisation technologies which offer users a satisfying experience of 3D content.

7 Getting Started

The CARARE project started on the 1st February 2010 and, at the time of writing, the project start-up phase is underway. Working groups are meeting to discuss and make

recommendations on metadata and vocabularies, and work is in progress to establish the CARARE repository and technical architecture.

A survey has been initiated to gather information from CARARE content providers about the content that they will be making accessible to Europeana and about their technical situations. We know that our partners are starting from different points, with a few already having advanced interoperable and remotely accessible online services while others need to set up their OAI-PMH repositories from scratch. Over the coming months as the survey brings more information about the situations of individual partners, CARARE will develop the advice, guidance and support needed to prepare for harvesting.

The CARARE aggregator will be implemented and tested during 2010, with trial harvesting from our content providers beginning towards the end of the year. Live harvesting will commence in 2011 with CARARE's first set of 2D contents becoming accessible to Europeana users with the Danube release in summer 2011.

8 Conclusions

With CARARE we are at the beginning of an exciting project which constitutes the next step on a journey towards realising the dream of bringing together Europe's archaeological and architectural heritage in a single access point which enables research across borders. We are building on previous work on data standards, terminology and technical infrastructure, and the efforts of heritage organisations, museums and research institutions to digitise the historic environment.

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AEgArOn – Ancient Egyptian Architecture Online

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Abstract. AEgArOn is an international three-year project striving for the open access online publication of high-quality plans and architectural drawings of ancient Egyptian buildings. These will give a globally accessible and reliable overview of the Pharaonic architecture including all major ancient Egyptian periods and building types. Moreover, the information is researched in detail, collected from the best available sources, combined in redrawn CAD-plans, checked on-site, and accounted for in extensive metadata. As a rule, actual state- and reconstruction-plans are provided, often complemented by plans of building-phases. Newly developed drawing conventions allow for immediate understanding and comparison between monuments. Long term sustainability and maintenance is ensured by incorporation into the UCLA Digital Library. Since starting in October 2009, and after six months eighteen PDF-files of five buildings have been completed and published online.

Keywords: Architecture, Digital Library, Documentation, Egypt, Metadata, Standards, Visualization.

1 Introduction

Architectural drawings of buildings dating to the Pharaonic period are often hard to find or have not been published adequately. It is therefore difficult to get an overview of the built environment of this time. AEgArOn, a three year project funded by the DFG and the NEH, aims at improving the present state of architectural representations by developing an open-access online archive of vetted plans. Published and in some cases unpublished plans of approximately 150 ancient Egyptian buildings are being collected and critically assessed, important details are checked in the field, and the plans are then redrawn in CAD according to a newly developed visual standard. The sources of the information are being made available in detail. The German Archaeological Institute Cairo (DAIK) and the University of California, Los Angeles (UCLA) are cooperating in this project¹. The data are collected in Los Angeles, transferred to

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new plans in Cairo, checked in the field, and published online and maintained in Los Angeles. The plans will be published through the web pages of the DAI and UCLA Encyclopedia of Egyptology (UEE) in various formats to ensure long term sustainability for different types of users: as AutoCAD-files (dwg), Acrobat-files (PDF), and pixel images (tiff). Eighteen PDF-files of five buildings are at this moment available at <http://www.dainst.org/aegaron>.

2 The Essentials

The goal of the project is to provide a comprehensive overview of Pharaonic architecture. The selected buildings should represent a balanced cross-section of ancient Egyptian architecture that takes into account the different types of buildings and monuments. Houses and palaces, small and monumental tombs, provincial- and nationally important temples, magazines, workshops, etc. are represented similarly, without limitation to or focus on the 'classical' era of Egyptian culture. In order to collect and present as much information as possible, all of the existing plans of a chosen building are checked and assessed. A selection of drawings is made, based on the quality of first hand information comprised. These are scanned on a flatbed scanner, and loaded into AutoCAD for redrawing. The most important measurements, especially the main dimensions, are compiled from the publications or measured from the original plans so that the inevitable distortion created by the scanner can be compensated. Each building has to be examined in detail so that the information given in the plan can be transferred to a standardized visual language. Whenever personal communication with the excavator or architectural historian cannot be established, this process will be accomplished through the published descriptions of the buildings, photographs, and, if possible, field checking (see below).

3 Visualization

3.1 Drawing conventions

Plans of historic buildings show considerable disparity in the evident standards of accuracy and visualization, e.g. a partly preserved wall in a floor plan may be indicated by hatching or solid black, representing a section view resulting from "cutting", or the wall may be shown from a top view with details of its masonry or brick pattern. This makes it more complicated to understand and compare the buildings and thus hampers architectural research—irrespective if it is in the field of Egyptology, building archaeology, or art history. All of the plans compiled in AEgArOn will display the same clearly outlined drawing conventions. The use of specified line thickness, types, and colors will enable immediate optical understanding of the building (fig. 1). Despite the attention to detail, it is inevitable that features are rendered abstract. For example, in the floor plans stone-by-stone renderings of walls are represented merely as a surface, which is then coded with the appropriate hatching representing the material; this also facilitates comparison with other buildings for which there are only less-detailed images. Initially, the drawings were rendered black and white, currently standardized color codes are being developed.

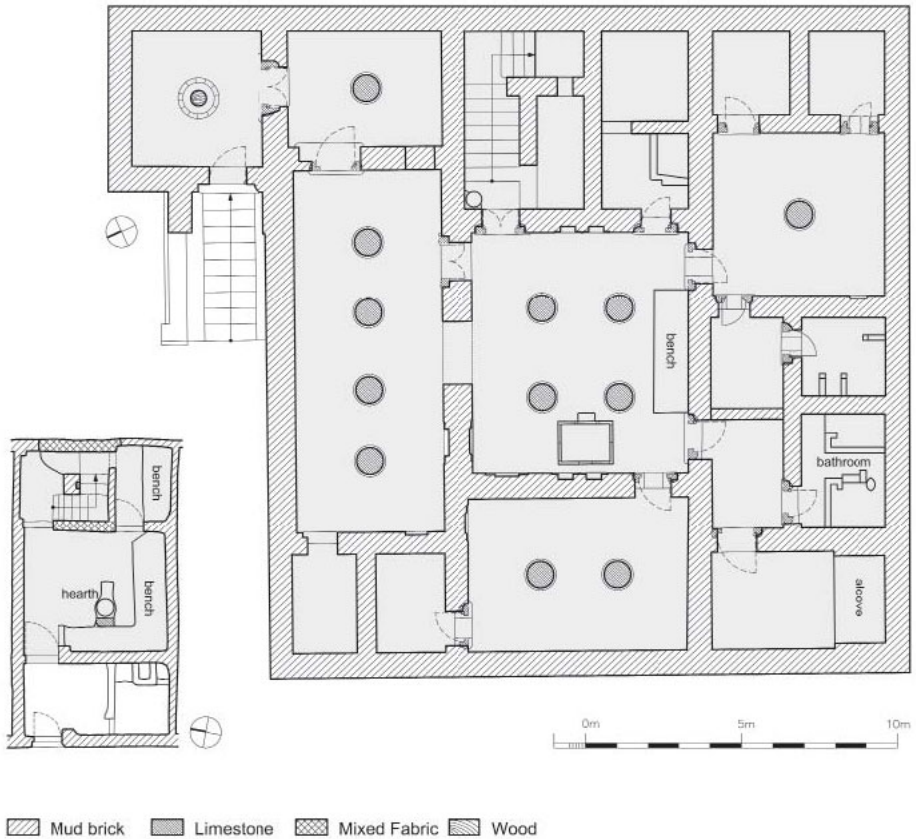


Fig. 1. Glimpse of the social stratification of a town in the 14th century B.C.: The reconstruction plans of two contemporaneous houses in Amarna on the same scale and with the same visual standards are placed side by side. The ground floor of the villa of general Ramose had a floor space of ca. 400 m² and consisted of a central hall, a large access area, and more than eight rooms and a bathroom. The numerous columns are indicators of not only a roofed area that was usually utilized for communal activity but also of an upper room. Furthermore, a number of outbuildings, a well, and a garden of ca. 694 m² belonged to the estate. The inhabitants of the house “Gate Street No. 8“, which was located within a walled-in exclave, were probably workmen in the necropolis of the town. They had at their disposal ca. 43 m² on the ground floor, which included a hearth in the front court. Here, too, we can assume that an upper room lay above, or at least an upper floor which was either unroofed, or contained shelters made from mats. Both houses were built of mud brick; the varying thickness of the walls must have had great influence on the indoor climate. Redrawn by S. Khamis after El-Saidi & Cornwell (1986, fig. 1.1) and Borchardt & Rieke (1980, plan 23).

3.2 Types of Plans

Often times, archaeological publications do not distinguish between actual state- and reconstruction-plans, e.g. by depicting destroyed parts of a building as existing in a plan which pretends to give the actual state. To call attention to this problem, actual

state- and reconstruction-plans of each building are produced as a rule in AEgArOn to compare (fig. 2). There may be exceptions if a reconstruction is not possible or a reconstruction plan is the only evidence of a destroyed building. Grossmann (1974, pp. 108-110) described the problem that many publications only contain reconstructions and that actual state drawings are ignored; he postulated to cease publishing reconstructions. Although his argumentation is convincing, the effect would probably be that outdated reconstructions are published instead of the actual state plans. If a building shows evidence of numerous reconstruction- or use-phases, the online publication will facilitate the publication of further drawings without high costs. For this a layer structure composed of 89 layers (Table 1) was developed, which is the basis of every drawing. The large amount of layers was generated due to the necessity to distinguish

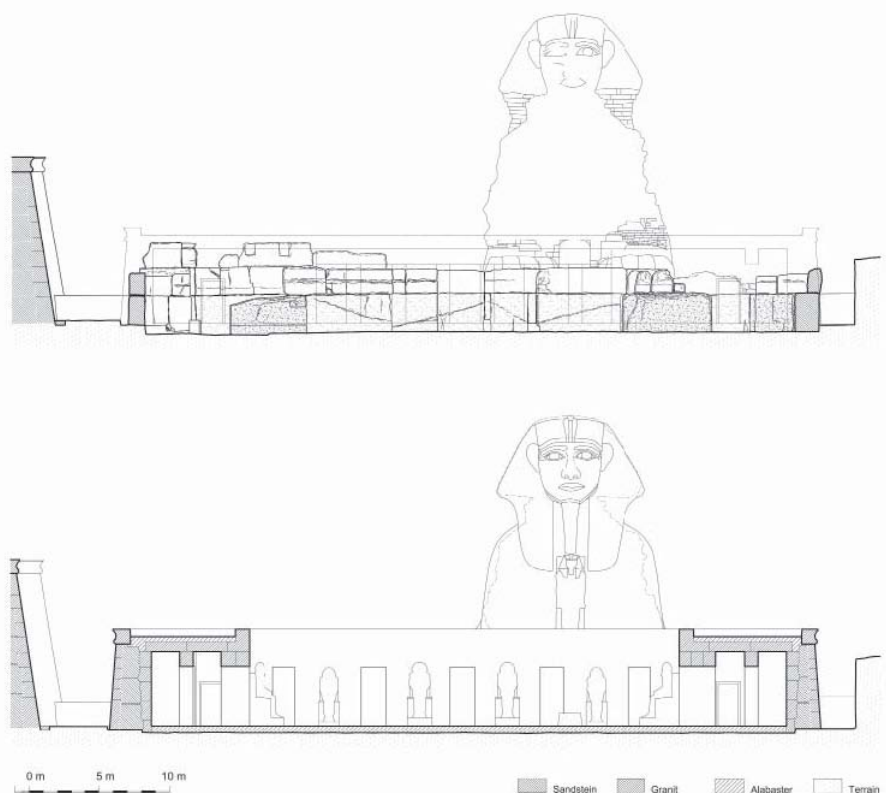


Fig. 2. Giza, Harmachistemple and Sphinx, 4th Dynasty, twenty-sixth century B.C., cross section with view towards the west, actual state and reconstruction. The drawings are compiled out of 80 layers in AutoCAD in a standardized layer structure, cf. fig 3. The cross sections are augmented by three floor plans, which display actual state, reconstruction, and building phases. For the first time, the temple and Sphinx have been drawn together in this form, which visualizes the combined effect of both monuments. The section lines through the temple, which deviate in the actual state- and reconstruction plan, are copied from Ricke (1970). Redrawn by S. Khamis after Ricke (1970, plan 3) and Lehner (1992, figs. 2 and 9).

different materials, actual state, building stages and reconstructions visually. Thus a distinction is made between reconstruction according to building archaeological findings (stage 1) versus reconstructions based on comparisons (stage 2) or reconstructions based on conjectures, which cannot be verified by the actual state (stage 3).

3.3 Why 2D?

A considerable part of documentation of cultural heritage today is done 3D, e.g. by laser scanning, and virtual 3D-reconstructions are becoming more and more popular. So why does AEgArOn stick to 2D drawings? Since it is the projects aim to give a well balanced overview over a large number of sites and building types, it is based on existing publication, which is almost entirely 2D. Sections are rarely published, and even several sections, floor plans and elevations are hardly sufficient to create an accurate 3D model without surveying the monument itself, especially when the building has irregular surfaces as partly destroyed structures usually have. Furthermore, 3D models are less able to represent details of construction, are less user-friendly due to the larger file size and cannot be included in printed works. 3D is a useful addition to the documentation of architecture, but will never replace 2D drawings. When presenting comparable material for a representative number of examples, there is at this time no alternative to 2D drawings.

4 Methods

4.1 Lessons Learned

Published plans of historic architecture display a surprisingly high number of discrepancies, which is particularly evident when there are numerous drawings of one building such as the Roman Temple at the Island of Philae (fig. 3a/b). Astonishingly it is the plans of the most famous buildings which are the most erroneous. This is probably due to them being copied more often for republication, while each copy adds new faults and errors. Therefore it is essential not only to republish drawings online, but to compare the available information and to verify it. Furthermore users of drawings will be enhanced to retrace the steps AEgArOn took when producing the individual plans.

4.2 Field-Checking

Each accessible building that is being published in AEgArOn is field checked during the drawing phase. Observations are recorded in a sketch, but measurements are not taken. Survey work in Egyptian monuments requires a permit, which must be requested three months in advance and contain the papers of all of those involved. The administrative efforts for 150 buildings cannot be met within the scope of this project. Relative to the time and effort spent, the increase in knowledge based on such sketches (fig. 3c) is significant. Most of the new findings are related to doors, blocking of openings, ceiling construction, and indications of structural changes. In order to record them in a plan, taking measurements would be desirable, but not necessarily essential. An approximate

Table 1. The layer structure compiled of 89 layers is the basis for all of the project’s drawings. The layers are either frozen [o] or unfrozen [✓] in the various types of plans, actual state [A], building phases [B], and reconstruction [C], which are managed in AutoCAD-Layouts.

Layername	A	C	B
Auxiliary lines (1)	o	o	o
Auxiliary lines (2)	o	o	o
Axes	o	o	o
Layout (Plot)	o	o	o
Section lines	(✓)	(✓)	o
Plan 01	o	o	o
Plan 02	o	o	o
Plan x	o	o	o
Actual state elem. in section	✓	✓	✓
Actual state destruction in section	✓	o	o
Actual state buildg. joint in section	✓	(✓)	(✓)
Actual state buildg. joint in elev. (1)	✓	(✓)	(✓)
Actual state buildg. joint in elev.(2)	✓	(✓)	(✓)
Actual state older elem.	✓	o	o
Actual state later edition in section	✓	(✓)	(✓)
Actual state later edition in elevation	✓	(✓)	(✓)
Actual state elem. in elevation (1)	✓	✓	✓
Actual state elem. in elevation (2)	✓	✓	✓
Actual state elem. in elevation (3)	✓	✓	✓
Actual state elem. above section line	✓	✓	✓
Actual state hidden edges	✓	✓	✓
Actual state sill	✓	o	o
Actual state stairs	✓	✓	✓
Actual state door jamb	✓	o	o
Actual state flooring	✓	o	o
Actual state depression	✓	✓	o

Layername	A	C	B
Actual state object	✓	o	o
Actual state damage floor (1)	(✓)	o	o
Actual state damage floor (2)	(✓)	o	o
Actual state destruction in elev. (1)	✓	o	o
Actual state destruction in elev. (2)	✓	o	o
Actual state destruction in elev. (3)	✓	o	o
Completion elem. in section	✓	o	o
Completion elem. in elevation (1)	✓	o	o
Completion elem. in elevation (2)	✓	o	o
Reconstruction elem. in section (1)	o	✓	✓
Reconstruction elem. in section (2)	o	✓	✓
Reconstruction elem. in section (3)	o	✓	✓
Reconstruction elem. in elevation (1)	o	✓	✓
Reconstruction elem. in elevation (2)	o	✓	✓
Reconstruction elem. in elevation (3)	o	✓	✓
Reconstr. elem. above section line	o	✓	✓
Reconstruction hidden edges	o	✓	✓
Reconstruction sill	o	✓	✓
Reconstruction stairs	o	✓	✓
Reconstruction doors (definite)	o	✓	✓
Reconstruction doors (suggested)	o	✓	✓
Reconstruction door jamb (definite)	o	✓	✓
Reconstruction door jamb (suggested)	o	✓	✓
Building Phase I	-	-	✓
Building Phase II	-	-	✓
Building Phase III	-	-	✓

Table 1. (Continued)

Layername	A	C	B
Building Phase I Reconstruction	-	-	✓
Building Phase II Reconstruction	-	-	✓
Building Phase III Reconstruction	-	-	✓
Building Phases Roofing	-	-	✓
Hatching Act. state elem. in section	✓	(✓)	(✓)
Hatching Act. st. later addit. in section	✓	(✓)	(✓)
Hatching Actual state Limestone	✓	(✓)	(✓)
Hatching Actual state Sandstone	✓	(✓)	(✓)
Hatching Actual state Hardstone	✓	(✓)	(✓)
Hatching Actual state Mud brick	✓	(✓)	(✓)
Hatching Actual state Burned brick	✓	(✓)	(✓)
Hatching Actual state Wood	✓	(✓)	(✓)
Hatching Actual state Roofing	✓	(✓)	(✓)
Hatching Reconstr. elem. in section (1)	0	✓	✓
Hatching Reconstr. elem. in section (2)	0	✓	✓
Hatching Reconstr. Limestone	0	✓	✓
Hatching Reconstr. Sandstone	0	✓	✓
Hatching Reconstr. Hardstone	0	✓	✓
Hatching Reconstr. Mud brick	0	✓	✓
Hatching Reconstr. Burned brick	0	✓	✓
Hatching Reconstr. Wood	0	✓	✓
Hatching Reconstr. Roofing	0	✓	✓
Header 200 Actual state Text	✓	0	✓
Header 200 Reconstruction Text	0	✓	✓
Header 200 Building Phases Text	0	0	✓

Header 200 Compass & Scale	✓	✓	✓
Room Number	(✓)	(✓)	(✓)
Layername	A	C	B
Label (1)	(✓)	(✓)	(✓)
Label (2)	(✓)	(✓)	(✓)
Height Indication (1)	(✓)	(✓)	(✓)
Height Indication (2)	(✓)	(✓)	(✓)
Coordinates (1)	(✓)	(✓)	(✓)
Coordinates (2)	(✓)	(✓)	(✓)
Original plan indistinct	0	0	0
Topography	✓	✓	✓
Key Legend			
Frozen Layer		0	
Unfrozen Layer		✓	
Layer frozen or unfrozen		(✓)	
Layer not used		-	
Actual State		A	
Reconstruction		C	
Building Phases		B	

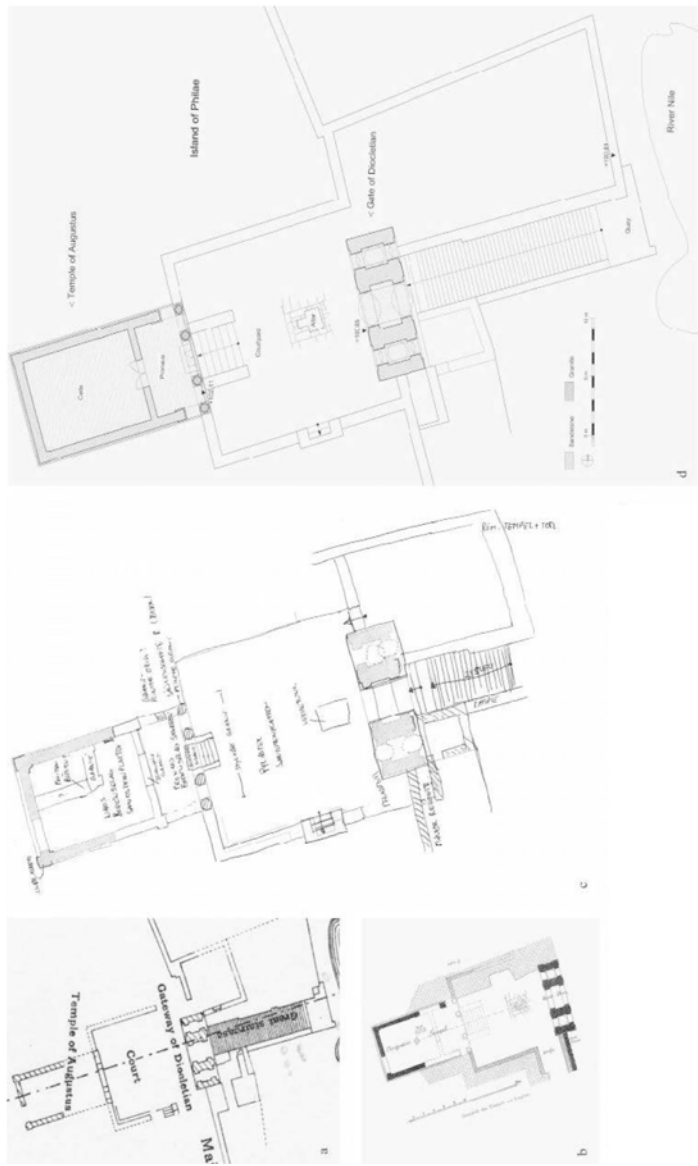


Fig. 3. Roman temple and gate, first and third centuries A.D. a) Actual state plan, detail from Lyons 1908, plate 1, floor plan. b) Actual state plan, Borchardt 1903, fig. 3, floor plan. c) Sketch after Lyons 1908, with mapping of actual state. d) New drawing M. Sählhof 2010, reconstructed floor plan (M 1-400). The plan is a synthesis of the older actual state plans, which were checked in a field survey of the building and were augmented by additional information.

record is better than an unpublished one. This step is indispensable also for well documented buildings especially when producing reconstruction plans. Buildings which are inaccessible due to lack of permission, state of excavation or preservation are checked by using photographs.

4.3 Metadata

In order to make the different steps in the development of the plans comprehensible, metadata are added to the drawings. As a critical apparatus they document authorship as well as the origin and the reliability of the information. This is contrary to the customary method of copying plans without checking the original or without any reference to their origin, during which the sum of errors increases and a wrong sense of up-to-dateness is conveyed since authorship is disregarded.



Fig. 4. Philae, Roman temple from southwest, 13-12 B.C., Photo by M. Sählhof 2010



Fig. 5. Philae, Roman gate from the east, ca. 300 A.D., Photo by U. Fauerbach 2009

5 Conclusion

AEgArOn aims at making a representative selection of ancient Egyptian buildings more accessible through detailed research and standardized visual language. The developed standards benefit Egyptology as well as architectural research, art history, and public interest. The project gives a broad overview of ancient Egyptian architecture and through original research in addition to comparisons of existing plans and elevations, contributes an important resource, which will form the basis for architecture as an important scholarly source.

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A Sustainable Repository Infrastructure for Digital Humanities: The DHO Experience

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Abstract. The Digital Humanities Observatory was created to support the long-term management of electronic cultural heritage resources for the digital humanities in Ireland. However, the project grant was for three years and the economic downturn has diminished opportunities for continued funding. The challenge is to demonstrate the importance and value of maintaining these e-resources, and to make it feasible for the resource owners to do so without the DHO if necessary. ICT systems can support cost effective and value-adding access and management of resources in a way that might be sustained in the short-term by organizations and projects that lack the funding, staffing, and skills to build and operate a digital preservation environment. In this project paper we describe how the DHO uses technology to promote the value of preservation and interoperability of e-resources, and to provide a means for achieving these goals in the face of significant sustainability risks.

Keywords: Digital Humanities, repository, Fedora Commons, Drupal, metadata, Europeana, sustainability.

1 Introduction

The Digital Humanities Observatory (DHO) [1] was established in 2008 as part of the Humanities Serving Irish Society (HSIS) [2] consortium to manage and co-ordinate the increasingly complex e-resources created in the arts and humanities throughout the Republic and Northern Ireland. Part of the mission of the DHO project is the provision of data management, curation, and discovery services supporting the long-term access to, and greater exploitation of, digital resources.

The DHO was funded for three years; in 2011 there is hope that the project can gain continuing funding in order to maintain its services, but this is far from certain. We are in the awkward, but not uncommon, position of promoting and supporting long-term access and preservation of digital resources in a potentially short-term context. The Blue Ribbon Task Force Report (2010) described the common economic and financial issues that impede implementation of digital preservation strategies, and identified three “technical actions” to overcome them: building capacity, lowering costs, and making operational an *option strategy* to hedge against irreversible loss.[3] The DHO response has been to build system sustainability and exit strategies into the information technology infrastructure that we provide our partner projects.

2 The DHO Repository

A key requirement to support the DHO mission is a central e-research repository for resources developed by HSI. The wide variety of e-resources that are candidates for the DHO repository, and the uncertainty regarding the requirements of that content, demanded digital asset management software that is flexible and extensible. As a resource intended to provide services and support to a variety of scholarly and digitization projects concerned with cultural heritage, the DHO repository must support heterogeneity across several dimensions:

- *Variety of resource types.* The repository is required to manage various media, such as images (manuscripts, historic pictures, etc.), encoded texts, audio recordings, and videos.
- *Variety of project goals.* Digital humanities projects vary in size, scope, and final aims; for example, while some projects need a comprehensive web site with user authentication, advanced search features, comment posting, and so on, others neither need nor can afford the development of those interfaces and thus require a more lightweight approach.
- *Variety of project abilities.* The DHO's involvement in the development of final deliverables varies according to the skills and resources available within the projects; some need support in all phases of development, while others may have the resources and expertise for in-house development and only avail of the DHO infrastructure for storage, indexing or interoperability.
- *Variety of long-term sustainability plans.* While some projects can afford the maintenance and update of their final deliverable, others face funding uncertainty themselves and have few options to keep their cultural heritage resources accessible in the long-term.

No single repository or digital asset management system can support the various resources and project requirements that we anticipate. We recognized the need for a modern service-oriented framework on which specific web applications could be easily built as needed. The foundation of such a framework is a repository platform that is open, based on web services, able to handle a variety of data and metadata models, and easy to extend.[4] Without the resources to develop a custom platform, we needed repository software that was mature and had a strong and dynamic set of tools being developed around it. The Fedora Commons [5] open source repository was the only system that met all these requirements. Fedora Commons supports a number of front-end solutions to access the e-resources stored in the repository, so we would not be locked into one set of tools for all the ways we would be publishing the resources on the web.

A key requirement of DHO web site development is the need to support both the development of thematic research collection project web sites, led by our partners and focusing on a single collection of resources, and the need to provide a generic cross-collection interface to discover and re-use resources across the whole repository. For this reason, the repository infrastructure has to be flexible and support different ways of implementing various features. Fedora Commons meets this challenge by being very modular and pluggable. For example, Fedora Commons does not have a built-in indexer and search engine, but comes with a generic easy-to-configure search service

that is based on Apache Lucene [6]. This service can be replaced or extended and the DHO (and many other Fedora repository projects) have added Solr, Lucene's enterprise search platform, to implement powerful full-text search, hit highlighting, faceted search, dynamic clustering, and other modern search features.

2.1 Front-Ends for Thematic Research Collections

After evaluating various classes of tools, including rich Internet application (RIA) and asynchronous JavaScript and XML (AJAX) frameworks, the DHO settled on integration with content management systems (CMS) as the most effective way to develop front-ends to the repository for thematic research collections. Although RIA and AJAX frameworks provide tools for accessing the Fedora API and could be used to develop front-end web sites, several factors led us to select CMS integration:

- The extant development skills and experience available in the DHO and partner projects.
- The primary focus that our partners have on publishing text-based resources rather than publications that require advanced graphics and animation.
- The flexibility and efficiency of server-side discovery and delivery for large data sets, as compared to client-based on-line exhibition solutions.

Our investigation into CMS integration looked at PHP-based Drupal [7] and Python-based Django [8]. Although Django offers many technical benefits with its object-oriented model-view-controller architecture, Drupal was selected for the sustainability that its large development and hosting community provides. Drupal is one of the most popular CMS, which means there are a very wide user base, ample choice of modules, and many hosting solutions for web sites. Human resources for developing Drupal modules and user interfaces are readily available. Because of the uncertain future of the DHO, technology sustainability is a more urgent requirement than technical elegance.

Integration with the CMS was achieved by means of the Fedora REST API Drupal module developed by the DHO and now available as open source software [9]. The Fedora REST API module is based on metadata harvesting, which adds some complexity to the process of ingesting and updating e-resources. In contrast, the Islandora [10] Drupal module, developed at the University of Prince Edward Island for integrating Drupal and Fedora, accesses the metadata in the repository and uses a Lucene index for searching, so new and updated resources don't have to be harvested to show up in Drupal. However, the Fedora REST API module has a flexible mechanism for mapping Fedora object structure and description to Drupal nodes, so it can work with the numerous core and contributed modules that operate on nodes, such as Search, Taxonomy, Views, Workflow, and the like. We felt this was a reasonable trade-off for cultural heritage resources that don't change much after they have been stored in the repository, but would benefit from new presentations and visualizations that take advantage of Drupal functionality.

The Fedora REST API module provides a programming interface to invoke Fedora Commons REST methods, including a PHP class that encapsulates all the REST API methods so they can be easily invoked from other Drupal modules. It also defines a type of content node ("fedora_object") that represents a digital object in the repository. One can define a new content-type in a custom module that invokes the Fedora

REST API module's hook implementations to add the Fedora object attributes to a node and, in an object-oriented sense, "extend" and "inherit" from the "fedora_object" content-type. A template module file is included to simplify the process of creating modules that extend the "fedora_object" content-type. Thus the Fedora REST API module, along with the Drupal framework, comprise a rapid application development environment that minimizes the procedural and SQL programming required to create web sites to publish digital cultural heritage resources stored in a Fedora Commons repository.

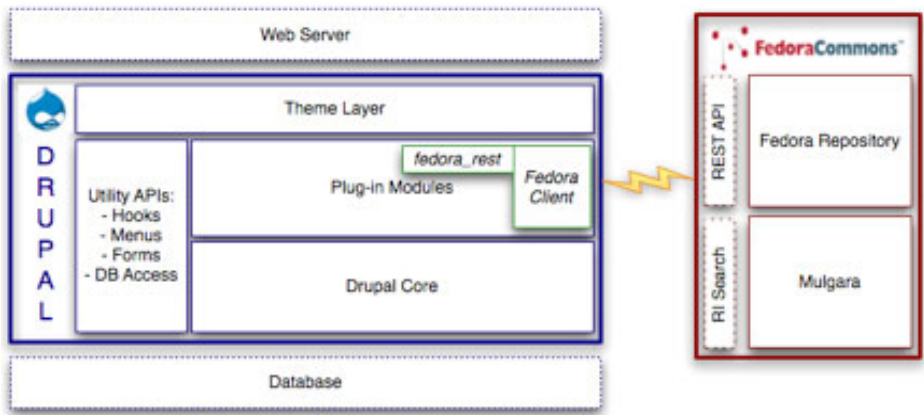


Fig. 1. Drupal-Fedora integration using the Fedora REST API module

We are also developing a mechanism for content to be imported and integrated into Drupal, so discontinuation of the DHO repository need not pose a threat to the preservation of each individual project. Their resources can be completely packaged in a Drupal web site that is hosted on any of the numerous hosting sites that support Drupal, and maintained by developers in the broad Drupal community. The content imported into Drupal using this mechanism will be structured as digital objects using the BagIt [11] format, so they can be easily ingested into future repositories as the opportunity arises. This supports our worst-case exit strategy: if the DHO is not funded and no repository solution is available for migration, a project can host a Drupal site with minimal effort and cost so their resources remain accessible, and the resources are also safe and verifiable (if not optimally re-usable).

A CMS solution provides a separation between the e-resources (stored in the repository) and supplementary content (like posted comments and resource tags to customise grouping and browsing) that is not inherently part of the e-resources themselves. It also offers opportunities to empower partners to customize their projects' websites with minimal intervention from DHO staff. Drupal user interface, user authentication, and search/browse facilities are provided by the CMS and configurable with simple administration web forms. And by leveraging Drupal's support of input filters, the Fedora REST API module offers additional levels of customization and empowerment:

very compact JSON format, making it more responsive than a pure server-based web application and less resource-intensive than an exhibit that must be loaded in its entirety into the browser.

While we were designing the search index for the cross-collection repository interface (known as DHO:Discovery), the DHO was working with the Irish Manuscripts Commission [13] to aggregate metadata describing digital content from national cultural institutions for the European cultural heritage portal Europeana [14]. We were able to leverage the Europeana project’s extensive experience reconciling heterogeneous metadata for cross-collection searching in our design for the DHO:Discovery index. Since the DHO repository contains a variety of metadata schemas, we are developing the DHO Repository Interface Metadata (DRIM) schema as a common denominator schema that can be used for DHO:Discovery. This schema is based on the Europeana Semantic Elements [15] (ESE v3.2.1) schema, which is a flexible metadata standard that allows heterogeneous resources to interoperate while presenting a very low barrier to projects that want to be included in the portal. The current draft of DRIM adds four additional elements to ESE v3.2.1, for linking to resources and browsing by facets. These extensions are given in Table 1.

Table 1. DRIM extensions to Europeana Semantic Elements v3.2.1

Element name	Attributes	Description
dho:collection	dho:url	Name of the thematic research collection(s) that the resource is a part of.
dho:datastream	dho:url dho:mime	An unambiguous URL and label for retrieving part or all of the content of the digital object.
dho:partner		Name of the DHO partner providing the resource.
dho:year		Date of creation of the original analogue or born-digital object.

We are creating crosswalks for deriving DRIM from any kind of metadata that is deposited in the DHO repository. The DRIM is then indexed using Solr to create a coherent cross-collection search facility. By following the ESE specification and the Metadata Mapping & Europeana Normalisation Guidelines for the Europeana Prototype v1.2 [16], the DHO is also ensuring that the metadata in the repository can be easily transformed and contributed to the Europeana digital library.

3 Current Status

The first thematic research collection based on the DHO Fedora repository and Drupal, The Doegen Records Web Project [17], went live in November 2009. This digital

archive of recordings in Irish-language dialects, made during 1928-31, comprises an important audio collection of stories, songs and other material. The collection includes 137 Gaelic speakers from 17 Irish counties. The Doegen Records Web Project web site is fully bilingual, with both English and Irish language versions built with Drupal internationalisation and translation features. It offers a unique resource for linguists, social historians, anthropological researchers, educators, musicologists, genealogists, local communities, and anyone interested in Ireland's cultural heritage. The materials provide a fascinating and priceless legacy of now extinct Irish-language dialects. Users can browse and listen to these recordings and appreciate the spoken record of the early twentieth century in rural Ireland. During the first four months of 2010, the website received over 2,000 visits.

4 Future Work

The Doegen Records web site will be greatly enhanced during the Summer 2010 with the addition of information about the speakers, and transcriptions and translations of the audio files. The project team is adding this additional content to the repository through a management interface built with Drupal and the Fedora REST API module. The project is also considering allowing mediated comments for scholars and the general public to annotate recordings, something that is easily implemented with Drupal and the Fedora REST API module.

At the time of writing, two other thematic research collections have been ingested into the repository, and their websites are being developed using Drupal and the Fedora REST API module. Additional collections will be ingested into the repository and their websites will be developed in the following months. This will be a test-bed for the rapid application development and customisation features of the Fedora REST API module, as the different collections will require quite distinct front-end web presentations. Ingestion of further collections will also greatly increase the quantity and utility of items accessible through DHO:Discovery.

We are continuing to refine the DRIM schema, informed both by our DHO: Discovery implementation experience and developments in the Europeana project. We are currently verifying compatibility with the latest version of the Europeana Data Model [18]. DHO:Discovery will offer faceted browsing and full-text search on some of the DRIM elements, a video/audio player, and a multi-resolution image viewer. Additionally, a key aspect of the interface is to provide a link to each item in the thematic collection web site where the item is shown in its original context. DHO:Discovery is currently in a prototype stage. At the time of writing, initial user testing is planned within the next month and a first release is scheduled to be launched in September 2010.

5 Conclusion

The political and economic context in which the DHO project was created and operates presents a dilemma: How do we support and promote best practices and technology for the long-term access and re-use of digital resources in a short-term project?

From a technology perspective, the DHO has met this challenge by creating systems that are exemplary and sustainable:

- Rather than describing our digital repository as a preservation archive, it is promoted as an exemplar repository for storing, managing, discovering and delivering digital humanities resources.
- Rather than developing a few highly customized web sites for cultural heritage collections, we created a rapid web site application development environment that leverages the Drupal content management framework to empower projects to do as much customisation as they are able using a range of skills from web admin forms to XSLT to PHP programming.
- Rather than enforcing strict consistent metadata requirements on all projects, we deployed a low barrier of entry metadata schema that can be used to demonstrate the value and importance of conforming to minimal standards in order to make project outputs interoperable.
- Rather than locking projects into a technology infrastructure dependent on the DHO's sustainability, we created infrastructure that is easily sustainable on its own, using commodity hosting and development resources.

None of these solutions are ideal; all involve trade-offs that must be considered with regard to project goals and risks. But significant risks to project funding and sustainability are prevalent in all initiatives that endeavour to research, manage, preserve, and disseminate the rich and diverse cultural heritage of the world. At the DHO, the current environment has forced us to find a balance between the immediate need to publish scholarly results and the imperative that these results be accessible for future uses and investigation.

Acknowledgments

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A Simple Approach to Link 3D Photorealistic Models with Content of Bibliographic Repositories

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Abstract. Linking 3D photorealistic and virtual reality models with contents of bibliographic repositories and resources is needed for archeological and historical analyses, public understanding of ancient settlements, and simple common sense studies using web content. As the Web 2.0 is used more and more by the community, it will help to deepen the knowledge of many interested internet users. Within this paper, a combination of 3D photorealistic modeling and content of bibliographic repositories, which describes the history of the Hirsau Abbey, Germany, is presented. In particular, it will serve for the special needs of the Verein “Freunde Kloster Hirsau e.V.” which is a registered association for taking care of the Hirsau Cultural Heritage site. The 3D photorealistic models have been acquired by means of static LiDAR and HD close range photogrammetry.

Keywords: 3D Photorealistic Model, Virtual Reality Model, Bibliographic Repository, Cultural Heritage, LiDAR, Close Range Photogrammetry.

1 Introduction

Up to now, there are two worlds of representing and maintaining cultural heritage objects: the geometry world and the semantics world. An efficient and direct link is missing. A more advanced approach would be to build software agents which snoop the Web just to find out references describing the single cultural heritage object. Thus, an effective procedure to build a bridge across the two worlds is extremely required. This bridge allows finding sources and references related to the desired cultural heritage object.

As a matter of fact the Web 2.0 is frequently used and easily obtainable to a larger and larger degree by the community. This indicates that simple approaches are needed to combine 3D photorealistic models with contents of bibliographic repositories and resources. Moreover, many interested internet users prefer to deepen their specific knowledge. Additionally, many fields of study and different applications such as archeological analyses, historical findings, public understandings of ancient settlements and simple common sense studies using web content need such a link. Quite similar ideas have been introduced already. On the one hand, it was proposed in the field of archaeology by the Information Centre for Archaeology (ArcheoInf), Bochum/Germany. ArcheoInf directs at having a combination between primary acquired data from different archaeological excavations and 2D field surveys. On the other

hand, this basic idea is also presented in the FOCUS K3D project. This project works towards promoting the usage of semantics in 3D content modeling and processing and focusing at virtual product modeling and cultural heritage.

Moreover, the current 3D COFORM project hides similar ideas and aims at advancing the cutting edge in 3D digitisation and 3D documentation as a common choice for digital preservation in the cultural heritage domain. This work will contribute to the European Digital Library (EDL) Project. The goal of the EDL project is to integrate the bibliographic catalogues and digital collections of several national libraries in Europe.

In our application, this link will, on the one hand, contribute to the needs of the “Verein Freunde Kloster Hirsau e.V.”, which is a registered association for taking care of the Hirsau Abbey site. On the other hand, it will offer Internet users to get the right bibliographic content associated with parts of the corresponding 3D virtual reality model.

The paper deals with a basic approach using simple web technologies to overcome this gap between the two worlds. This approach is considered as a first and simple step to provide the desired information and references. Our next challenge will be to build software agents (or Internet “bods”) as a more advanced technology.

In a first pilot project we have implemented the link of a 3D photorealistic model of one of the buildings of the ruins of the Hirsau Abbey, which is called the “Hunting Lodge”, with content of bibliographic repositories. Therefore, the work in this paper is a starting point and serving for the special needs of the complete project, which is aiming towards a complete digital preservation of the whole area of the Hirsau Abbey. In addition to that, this project contributes to the CyArk 500 Project which aims to digitally preserve 500 of the most important heritage sites in the whole world [1].

2 Data Collection and Preparation

The data collection, which has been used for our application, was performed in cooperation with the “Friends Association Monastery Hirsau (Verein Freunde Kloster Hirsau e.V.)”, Calw/Germany and the Public Office for Historical Monuments' Care (Landesamt für Denkmalpflege), Stuttgart/Germany. The overall goal of the project is to generate a 3D virtual reality model of the Hirsau Abbey, Germany (as depicted in Figure 1).

2.1 Hirsau Abbey

Hirsau, a village in the northern part of the Black Forest, today a suburb of Calw/Germany, has a great history. In particular, the Hirsau Abbey, once known as the Hirschau Abbey (most probably because of the Swabian dialect or may be because of many deers around) was one of the most prominent Benedictine abbeys of Germany. Founded around 830 AD by Count Erlafried of Calw, it served as an abbey until it was destroyed by French soldiers in 1692. By the way, the famous William of Hirsau, abbot from 1069 to 1091, introduced the Astrolabe for measuring latitude positions. Therefore, the Hirsau abbey served already more than one

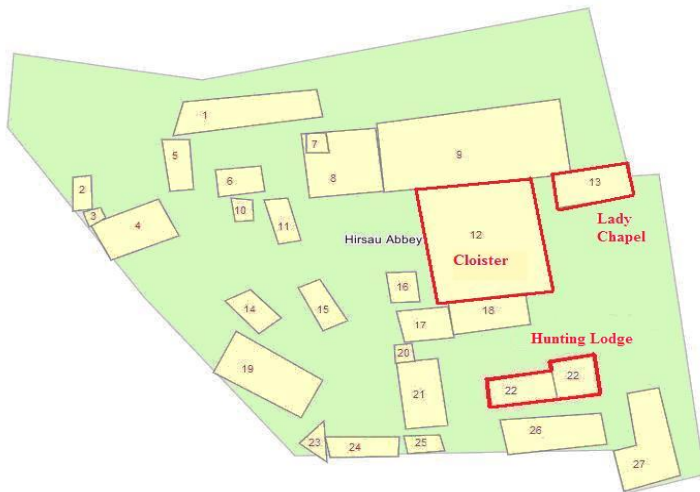


Fig. 1. Hirsau Abbey buildings (ground plan information)

millennium ago for geodetic purposes, a fact not well-known to the geodetic community. Today, just ruins are found - one can see the Cloister, the ruins of the Hunting Lodge, the Lady Chapel and some other Hirsau Abbey Buildings, which are demonstrated in Figure 2.

2.2 3DPhotorealistic Modeling of the Hunting Lodge

3D photorealistic models play a fundamental part in case of risk, damage and archiving and they serve for cultural, touristic and advertising purposes. Those models are increasingly demanded in many fields of application. One of the most important applications is the 3D preservation of cultural heritage sites.

For this purpose, both static LiDAR and close range photogrammetry have been employed successfully for the precise documentation of our cultural heritage study [2,3,4]. Terrestrial laser scanning has been used for collecting highly accurate 3D geometric models. The Leica Scanstation HDS 3000 has been used for data acquisition. Moreover, the 3D virtual reality models are obtained by means of data fusion linking static LiDAR with High Definition (HD) close range photogrammetry. Here, to perform the texturing of the 3D models and for the photogrammetric reconstruction, a digital metric camera, Nikon D2X has been employed. More details can be found in [5].

Figure 3 describes the methodology used from the data acquisition (3D laser scanning and photogrammetric techniques) to the final generation of the 3D virtual reality model using the Google SketchUp program. This chart illustrates the process followed to transform the 3D laser scanning data (point clouds) to a virtual reality model. Using Leica's Cyclone program, registration, georeferencing and modeling of point clouds are achieved. Then, corrections and texturing processes of the previous model are followed, using the Google SketchUp program to get a complete 3D virtual reality (VR) model in the end.



(a)



(b)



(c)



(d1)



(d2)

Fig. 2. (a) Hirsau Abbey (© Große Kreisstadt Calw und Oberfinanzdirektion Karlsruhe Copyright 1991). (b) The Hunting Lodge. (c) The Lady Chapel. (d1,2) The Cloister.

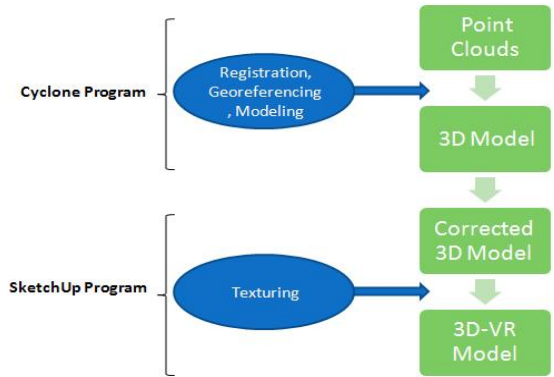


Fig. 3. Workflow for the generation of 3D-VR Models in Google SketchUp

In this paper, we deliver a 3D photorealistic model of one of the biggest parts of the ruins of the Hirsau Abbey, which is called the Hunting Lodge (Figure 4).



Fig. 4. The Hunting Lodge, snapshot for the model in SketchUp [5]

This work is the first step of a complete project, which is running at the Institute for Photogrammetry (ifp), University of Stuttgart, since July, 2009. By the way, the ifp has a very good experience regarding cultural heritage documentation, more information is given by [3,6,7,8]. The overall aim is to deliver a complete 3D photorealistic model of the whole Hirsau Abbey site. The photorealistic model will serve for cultural, archiving and touristic aims.

Figure 5 depicts two examples of our ongoing work, where the 3D virtual reality models of the Cloister and the Lady Chapel are generated. In the near future these models will be available for free in Google Earth.

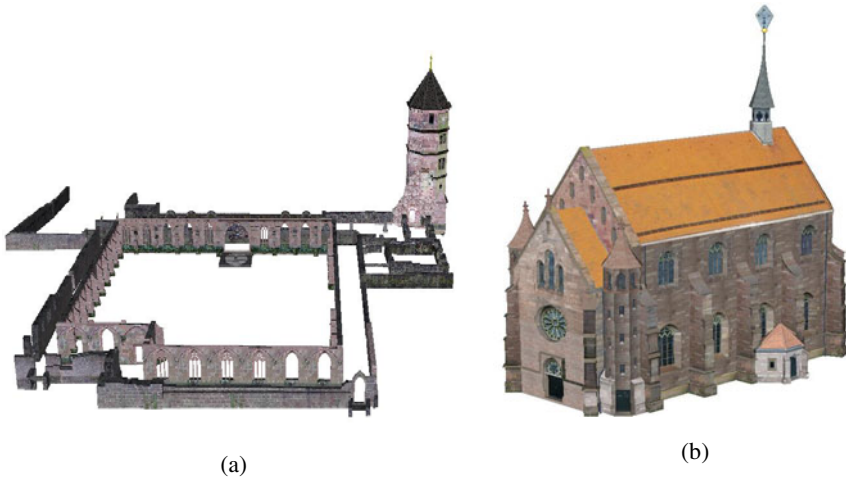


Fig. 5. (a)The Cloister [9]. (b) The Lady Chapel [10].

3 Linking Two Worlds in Digital Preservation – Geometry and Semantic

The idea of our approach is to find an easy way linking an uploaded, web-accessible 3D photorealistic model of any Cultural Heritage site with web-accessible content of bibliographic repositories. Our focus is to use open and free-of-charge sources just to maintain the demands of the public. Moreover, these simple technologies were selected due to the fact of wide public usage.

To do so, we combined successfully the community-based Wikimapia and the Google 3D Warehouse, first to find the site using Google Maps and secondly, to watch the site in three-dimensions by means of Google Earth with a provided link to bibliographic resources and related texts.

3.1 Integration of the 3D Virtual Model in Google Earth

To link the 3D virtual reality model with bibliographic resources and because of the large and open usage of virtual globes, the first step is integrating the 3D virtual reality model with Google Earth. Concerning this step, we could use the Leica Virtual Explorer Architect (LVE), but we decided to use Google Earth to have more options regarding visualization and 3D scene generation. More information can be found in [11].

To integrate the 3D photorealistic model with Google Earth, we first have used the Google SketchUp software to place the model and export it to Google Earth with KMZ format, which is the standard exchange style to integrate 3D photorealistic models into Google Earth. After that, we created an account in the Google 3D Warehouse to have the opportunity to upload our KMZ file to Google Earth. The Google

3D Warehouse is a free online repository where you can find, share, store, publish, and collaborate on 3D models. As a result of this, the 3D photorealistic model of the Hunting Lodge becomes open for the public and can be visualized freely and easily as in Figure 6.



Fig. 6. The Hunting Lodge in Google Earth

Uploading the 3D virtual reality models into the Google 3D Warehouse is considered the easiest way to share any model of a site with millions of internet users. To watch our 3D virtual reality model you may visit the Google 3D Warehouse website and type in the name, the Hunting Lodge, and then you will get the webpage which is shown in Figure 7. Through this webpage, we have the opportunity to view the model in 3D or install the model's KMZ file to be visualized using Google Earth. Furthermore, it provides an external link to Wikimapia where you can find the desired references and sources that describe the Hunting Lodge.

3.2 Wikimapia Website

Wikimapia is an online map and satellite imaging resource that combines Google Maps with a wiki system allowing users to add information, in the form of a note to any location on Earth. The Wikimapia project, created by Alexandre Koria-kine and Evgeniy Saveliev, was launched on May 24, 2006 and is aiming towards "describing the whole planet Earth".

As a matter of fact, there is no other option to add a direct link between a 3D model integrated in Google Earth and bibliographic resources. So, using Wikimapia, we used a 2D shape, which refers to the footprint of the 3D model, to link it to the 3D model which is already stored in the Google 3D Warehouse. We prepared the web

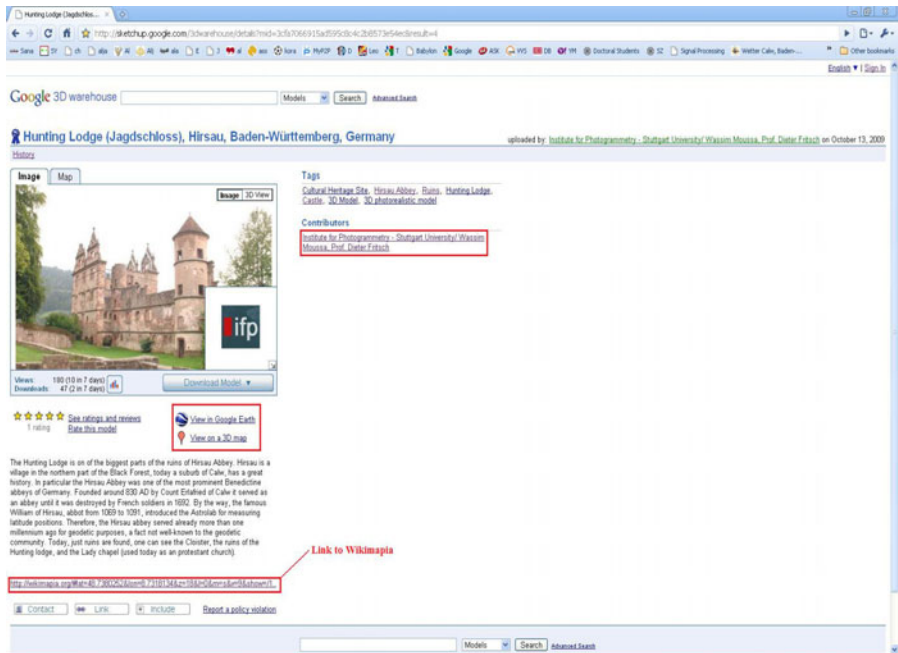


Fig. 7. The Hunting Lodge in Google 3D Warehouse

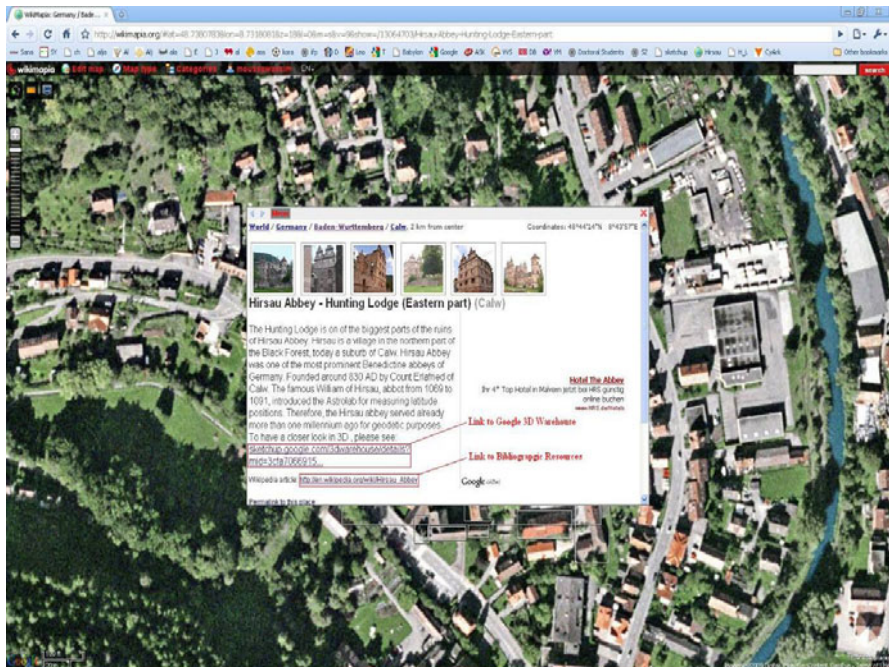


Fig. 8. The Hunting Lodge in Wikimaps

page which relates to our model, the Hunting Lodge, by adding information about the site and uploaded few pictures collected by us. Moreover, explicit links between the 3D model and the bibliographic resources were allocated.

By typing in the Wikimapia homepage and the desired name (Hunting Lodge) will lead to the Wikimapia page. It shows all the above mentioned information and guides the interested user to get answered any enquiries about the Hunting Lodge, Hirsau Abbey. Figure 8 demonstrates the web page and its possible options and deliverables.

4 Conclusions

The combination by linking 3D photorealistic models with content of bibliographic resources, which describe the history of the cultural heritage sites, is highly needed. We presented a simple idea which is considered as a starting point to connect both the geometry and the semantics worlds. This link was missing for a long time. Our next step is to have an advanced approach which aims to build software agents for getting information about references describing each single cultural heritage object. We hope that our work in this paper together with our contribution to the CyArk project will not only gather both, 3D photorealistic models and their bibliographic resources, but will also help in globally preserving our collective history.

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A Working Environment for Management and Exploitation of Audiovisual Archives – ASA-SHS Project

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Abstract. This document describes the working environment developed by ESCoM laboratory (Equipe Sémiotique Cognitive et Nouveaux Médias, Fondation Maison des Sciences de l'Homme) during the ASA-SHS project (Audiovisual Semiotic Workshop for Human and Social Sciences). ASA-SHS is a R&D project financed by the French National Research Agency (ANR, Programme Blanc 2008) and targets to develop strategies of indexing and semiotic description for audiovisual resources in Social and Human Sciences. The environment developed by ESCoM is a complete environment for managing, describing and publishing audiovisual documents for research and learning. It consists more particularly in tools, resources and distant services for: 1/Management of audiovisual documents, 2/ Management of ontological resources, 3/Semiotic description of documents, 4/Publishing of documents in web portals, 5/Exploitation of documents in the form of publications dedicated to specific uses.

Keywords: ASA-SHS, Semiotic Audiovisual Description, Controlled Vocabulary, Ontologies, Description Template, Publication Template.

1 Introduction

ASA-SHS Project (*Audiovisual Semiotic Workshop for Human and Social Sciences*, <http://www.asa-shs.fr>) is a R&D Project, chosen and financed by the *French National Research Agency* (ANR, “*Programme Blanc Edition 2008*”, <http://www.agence-nationale-recherche.fr>). ASA-SHS is developed by ESCoM (*Equipe de Sémiotique cognitive et nouveaux medias*). It officially started on 1st of January 2009 and last for 36 months (Expected end on 31th of December 2001).

The audiovisual material used on ASA-SHS Project comes from the diversified and important (5000 hours of videos) collections of the *Audiovisual Research Archives* (ARA Program, <http://www.archivesaudiovisuelles.fr>), also developed by ESCoM.

The working environment developed for ASA-SHS Project is the result of thinking made since 2001 for the ARA Program. In consequence, it is an evolution of an existing environment, combining improvements of existing tools and new technologies, specifically developed for the project.

This environment should answer 2 complementary contexts of use of audiovisual documents:

- The standard context of production/publication as experienced for the *Audiovisual Research Archives Program* – whose results are the bases of *ASA-SHS* Project.
- The context of *ASA-SHS* Project, based on complex problematic of semiotic description of audiovisual documents and specialized publications, which constitute a great re-exploitation and promotion for an important collection such as the *ARA* collection.

2 General Overview of the Environment

2.1 User Roles

We can distinguish 5 kinds of roles in this working environment (cf. *Fig. 1*):

- *Cogniticians* configure the environment by editing controlled vocabulary, types of medias, description templates, but also parameters and templates of publication of the web portal.
- *Producers* register new audiovisual productions, via the web portal.
- *Analysts* describe the audiovisual documents.
- *Translators* translate the environment vocabulary.
- *Authors* manage the publications on the web portal.

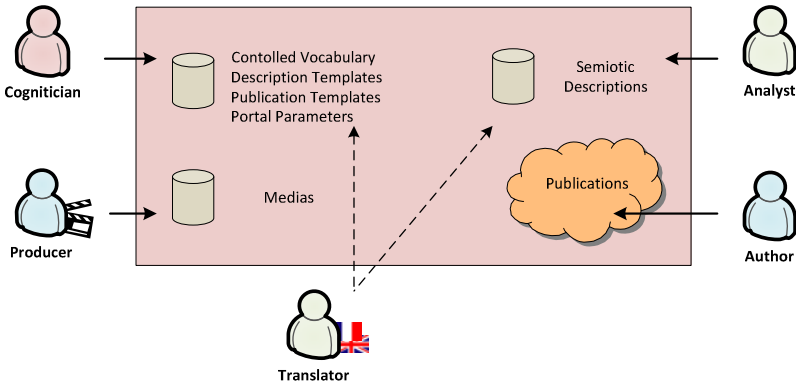


Fig. 1. Roles in *ASA-SHS* Environment

2.2 Interfaces

The environment is composed of 3 main interfaces (cf. *Fig. 2*):

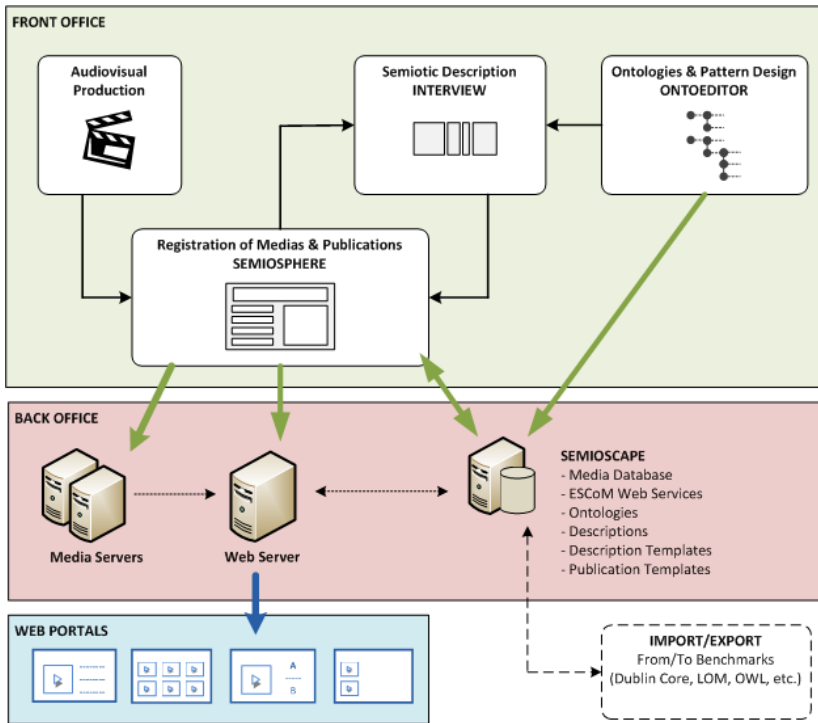


Fig. 2. Interfaces of ASA-SHS environment

1/ Semioscape: the heart of the system. This is the server with which the tools communicate. It contains all the resources of the system:

- A database storing every information about medias, controlled vocabulary, descriptions, etc.
- Business libraries that provide all necessary methods for reading, insertion, modification, transformations of data, and methods for rights control.
- Web services providing necessary resources and methods to user tools.

2/ User tools: two user tools are used during the pre-publication phase:

ESCoM OntoEditor:

This is a controlled vocabulary editor which provides an interface for the configuration of the system: ontologies, description and publication templates, translations, benchmarking, etc.

ESCoM-INA Interview:

This is the audiovisual semiotic workshop, co-developed with *French National Audiovisual Institute* (INA). It enables the cutting of the video clip and a very rich description of each sequence.

3/ *Semiosphere*: the web portal, developed on *ASP.Net* framework, on which audiovisual documents are published. An administration interface enables the authors to manage the media database, and the publications on the portal.

2.3 Semioscope

The architecture of *Semioscope* is composed of 3 main layers (cf. Fig. 3)

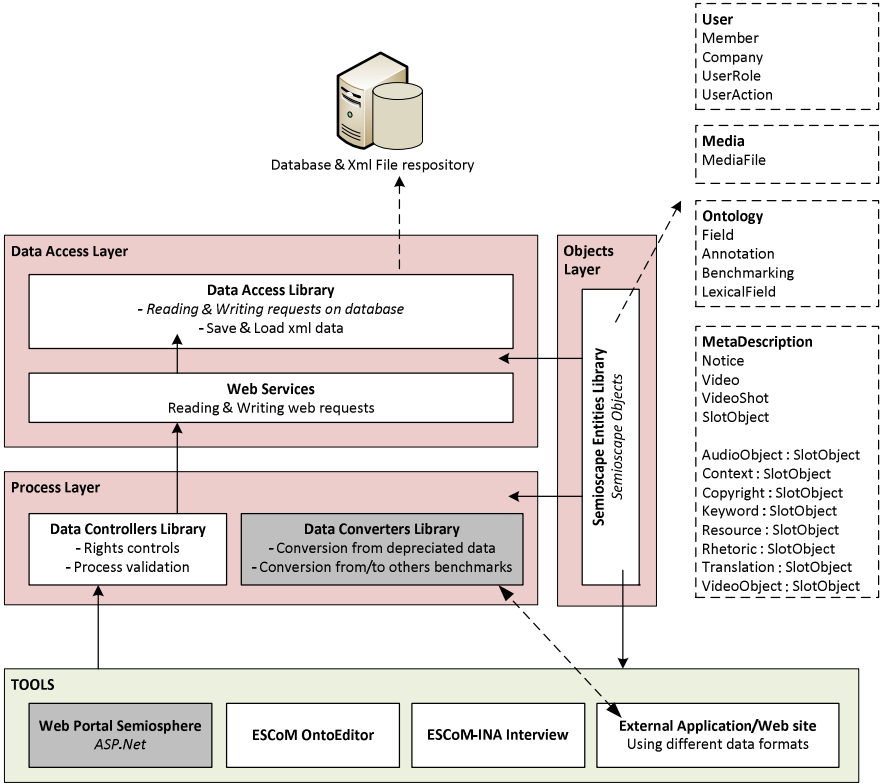


Fig. 3. *Semioscope* Architecture. In gray, parts which are still under development

1/ Objects Layer

The *Semioscope Entities Library* contains every object (in a proprietary format) used by the system, tools and web applications:

- *Ontology* object represents a controlled vocabulary. It is defined as a *Field* object, which contains a list of fields (this defines the structure of the vocabulary) and a list of *Annotation* objects which define the content of a field in any language.
- *MetaDescription* object is defined by a list of *Video* objects, which are defined by a list of *VideoShot* objects (corresponding to a sequence of video). Both video and video sequences are defined by a set of *SlotObject* objects

corresponding to the different elements that describe the video or video sequence (keywords, translations, audio objects, etc.).

2/ Data Access Layer

The *Semioscape Data Access Library* contains every method used for data handling:

- Requests on database (reading and writing requests)
- Load and save methods for data stored as files (mostly controlled vocabulary, stored both in database and file repository)
- These methods are called by web services. Tools access to data by calling the web services, enabling distant uses.

3/ Process Layer

The *Semioscape Controllers Library* contains every method used for checking the validity of any requested process:

- Check the validity of sent data
- Check if user has sufficient rights for any requested process (writing and reading request on every object)

The *Semioscape Converters Library* contains methods used for the transformation of data:

- Methods for transforming data saved in depreciated format (after a critical update of *Semioscape Entities* objects, this ensures that old data will still be usable)
- Methods that should convert data from/to others formats (MetaDescription / Mpeg-7; Ontology / OWL; etc.)

3 Semiotic Workshop

3.1 Controlled Vocabulary

ESCoM OntoEditor enables to register the system parameters, in a proprietary xml format. Thus, the cognician has a visual tool that enables him to define:

- Video formats (wmv, flash, etc.)
- Modes of video diffusion (streaming, progressive download, mobile, etc.)
- Video definitions (low, high definition, etc.)
- Description templates (cf. next chapter)
- Publication templates
- Benchmarks for data transformations, in order to reuse data in other technological contexts.

This controlled vocabulary is described in a hierarchical manner in the xml format. Beyond the internal name, user can define for each element of the hierarchy:

- Public name, abbreviation, locution,
- Definition, descriptions, examples,
- Link, picture,

- Its reference in every benchmark (LOM, Dublin Core, DEWEY, MPEG7, etc.)
- Information relative to description templates (cf. next chapter)

Finally, we can notice that each kind of this information can be translated in any language. More, *ESCoM OntoEditor* offers automatic completion functionalities, helpful for translator tasks.

3.2 Description Templates

The tool *ESCoM OntoEditor* enables habilitated users (“cogniticians”) to define and create dynamically the descriptive schemas (the “description scenarios”) by the means of which audiovisual clips or corpora of audiovisual clips have to be described and indexed (cf. Fig. 4)

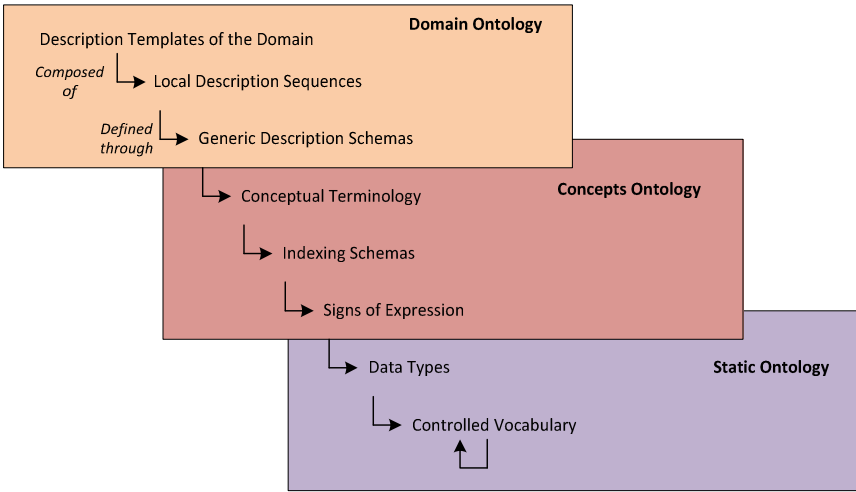


Fig. 4. Description Templates Structure

The specification and development of a set (or “library”) of description scenarios relies on three different categories of meta-linguistic resources:

1/ **The category “domain ontology”:** it enables the cognitician to define the empirically appropriate description models or scenarios of a selected and circumscribed domain of knowledge (such as the domain “cultural diversity”, the domain “literary heritage”, the domain “research in archeology”, etc.). Principally speaking, a model or scenario of description is composed of a selected set of conceptual terms (“concepts”, in short) which have (or which should be) indexed. Each model or scenario of description possesses a functional, a hierarchical and a configurational organization:

The functional organization of a description template

Distinguishes between several canonical functional fields of description of a video source such as:

- The description of the objet or domain of reference (i.e. the description of about what the video or a selected segment of video is);
- The description of the (spatial, temporal and contextual) localization of the object of reference;
- The production of interpretative comments;
- Etc.

The hierarchical organization of a description template

Each model of description is composed of a set of sequences (and sub-sequences) which are specialized in the one or the other functional field of description (description of the domain of reference, description of the localization of a domain of reference, etc)

The configurational organization of a description template

Each sequence is constituted of generic description schemas or objects that define the internal structure of a sequence. Each generic schema or object contains one or more conceptual terms to be indexed. A generic schema or object can belong to many different sequences. For instance, the generic object “Title” is composed of conceptual terms such as “Principal title”, “Subtitle” or again “Short title” and it defines – with other generic schemas or objects – each sequence which has to do with the indexing of, for instance, documents, intellectual or artistic works, literature, etc.

2/ The category “concept ontology”: it contains the central meta-linguistic resources of a template or scenario of description of video clips or corpora of video clips, i.e.:

The conceptual vocabulary of the ASA-SHS domain

Each template or scenario of description is composed of a selection (a set of) conceptual terms belonging to this vocabulary.

The indexing schemas

These schemas defines how a conceptual term has to be indexed – as a proper noun, as a common noun or nominal expression, in form of a defining phrase, by the means of non-linguistic means such as acoustic or visual images as well as in form of controlled vocabularies, etc.

3/ The category “static ontology”: it includes a set of files which are necessary for the technical environment of *ASA-SHS*

- Definition of data types, i.e. basic types (text, numeric, date, etc.) and user-defined types (writer, politician, country, etc.);
- Controlled vocabulary, in which words can be defined into several categories;
- Media configuration (formats, definitions, diffusion modes);
- Ontology versioning;
- Etc.

Example

The figure below (Fig. 5) shows an example of nested schemas. This example was taken from an ontology about Literature called *ALIA*.

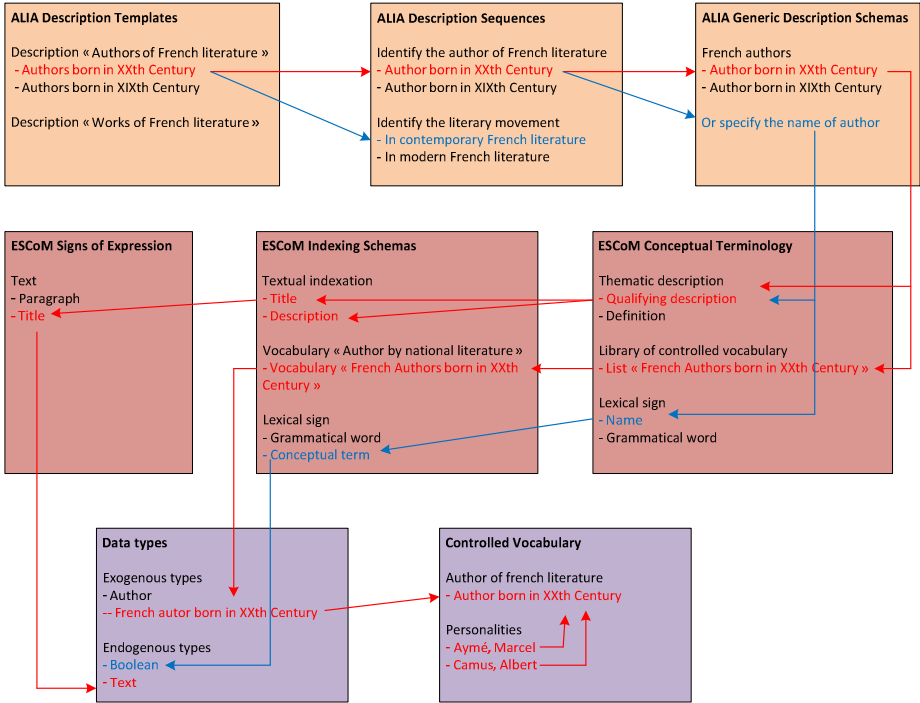


Fig. 5. Example from ALIA ontology

1/ ALIA domain ontology defines specific description templates in literature, such as “Authors of French Literature born in XXth Century”, or “Works of French Literature”. “Authors of French Literature born in XXth Century” can be described using 2 different sections:

- From the static list of French authors born in XXth Century ;
- By specification of the author (if not included in the static list).

2/ These sections use description templates from the ESCoM’s Concepts Ontology. Note that they both have a common resource: “Qualifying description”. This resource is defined by a title and a description.

3/ Finally, sections of concepts ontology are finalized when nested with an element of static ontology: this specifies the type of data corresponding to the section. In our example, title is typed as “Text” (then description form will dispose this element as a text box). Conceptual term is defined as a boolean (description form will dispose this element as a check box).

List of French authors is nested with a section of the controlled vocabulary: in this case, description form will dispose a list box. To provide this list of authors, we use a property particular to the controlled vocabulary: sections can be nested with sections inside the vocabulary. This enables to associate a vocabulary with different sections (in our example, we need to define Albert Camus as an author, a philosopher and a journalist). Thus, the list of authors will not only display elements under the “Author born in XXth Century” section, but also elements nested with this section.

3.3 Semiotic Description

The name of the central tool for the concrete segmentation and description of video clips is *ESCoM-INA Interview*, co-developed with *INA (Institut National de l'Audiovisuel)* in Paris, France. The concrete description/indexing of a video clip is performed on three levels:



- The production of a kind of “meta-description” of the description itself (title, author, summary, etc.)
- The production of a global description of the video clip as a whole
- The segmentation of the video clips in a set of (user-determined) sequences and the description of each sequence.

The principal tasks of a description/indexing of a video clip and/or its sequences are concerned with the eliciting and structuring of the main features that characterize the content of a video (or of one of its sequences). In this sense, the description of a video or one of its sequences by the means of the previously defined templates or scenarios of descriptions covers:


- The *description of the topic* of a video (or of one of its sequences);
- The *description of the “visualization”* of the topic by the means of audiovisual techniques;
- The *description of the sound level* of a video used for the acoustic expression and communication of a topic;
- The *description of pragmatic aspects* characterizing the specificity of a video clip and/or of one of its sequences (target public, target uses, ...);
- The *enriching of a video* or of one of its sequences by the means of comments, explanations, aids, links, references, etc.;
- Etc.


Description forms of the description of topics are displayed according to nested schemas designed in the domain ontology, as explained in the previous chapter:

- The analyst select a description schema in a list depending on the selected domain
- The hierarchy of elements to describe is displayed according to the “definition formats”
- When this hierarchy reaches the lowest level, the level of data types, a form control is displayed, depending on the data type (text input, date select, check box, list of elements from the static vocabulary, etc.) (cf. examples on Fig. 6 & 7. Note that they follow the example presented on Fig. 5).


*Type :  


1. Séquence "Identifier et présenter un écrivain français né au XXe siècle"

1.1. Schéma "Sélectionner un écrivain français né au XXe siècle"
Liste ASA "Les écrivains français nés au XXe siècle" 

1.2. Schéma "Ou, à défaut, préciser le nom de l'écrivain"
Personne : * 

2. Séquence "Identifier le courant approprié dans la littérature française contemporaine"

2.1. Schéma "Sélectionner le courant littéraire français à l'Epoque Contemporaine"
Liste "Courant littéraire français à l'Epoque" 

2.2. Schéma "Ou, à défaut, préciser le courant littéraire..."
Courant littéraire à spécifier : * 

3. Séquence "Localiser dans le 20e siècle français"

Référent "Histoire de la littérature française" :

3.1. Référent "Histoire de la littérature française"

Référent "La période du 20e siècle français" :

Fig. 6. Example of an ALIA Description Form

Liste "Courant littéraire français à l'Epoque Contemporaine"

Vocabulaire normalisé ASA "Courant"

☐ 01 Le Futurisme

☐ 02 L'Algérisme

☒ 03 Le Surréalisme

☐ 04 Le Dadaïsme

☐ 05 Le Populisme

☐ 06 Le Réalisme Socialiste

☐ 07 La Littérature Proletarienne

2. Indexation par un nom propre équivalent

Expression équivalente :

Expression alias :

3. Indexation qualifiante

Paragraphe long :

Fig. 7. Example of a Concept Form

4 Semiotic Processing and Publication

At the level of the indexing, the system enables the cognitician not only to configure the global concepts, but also their specialization by domain.

At the level of publication, the philosophy is exactly the same: the system can publish the audiovisual documents - and their corresponding descriptions - on different web portals. Thus, each portal has its own visual identity, its own knowledge domain, its own publication templates, etc. In consequence, the same audiovisual description will be used in various ways on each web portal. In the context of ASA-SHS Project, 3 portals have been developed:

- “Atelier à la Rencontre des Cultures” (ARC, <http://semioweb.msh-paris.fr/corpus/arc/>)
- “Atelier Littéraire d’Ici et d’Ailleurs” (ALIA, <http://semioweb.msh-paris.fr/corpus/alia/>)
- “Atelier des Arkéonautes” (ADA, <http://semioweb.msh-paris.fr/corpus/ada/>)

Using the administration interface of a portal, an author can manage different kinds of publications:

4.1 “Standard” Publications

This is the default publication template, which improves the one already existing on the portal of the *Audiovisual Research Archives*. In this case, a publication is organized using a factual point of view: first, the author defines an event, and organizes it hierarchically (for example, a seminary divided in courses). Then, the author associates an audiovisual description to each part of the event, which means that each video clip will be published as an “hypermedia folder”:

- General presentation of the video clip, actors, topics, etc.
- Access to each sequence of the video clip from the list of chapters
- A video-lexicon is displayed, offering an access to the sequences associated to each term of the lexicon.
- A list of main topics is displayed, offering an access to the sequences associated to each topic.

4.2 Specialized Publications (or « Re-publications »)

These publications use advanced semiotic descriptions, produced in very specific contexts. They are either associated with an existing publication, as complementary publications, or combined in new fictive events. These republications are displayed from specific templates. Here are some examples of templates developed for ASA-SHS Project:

1/ The pedagogical folder: publication adapted to a particular pedagogical exploitation, i.e. a pedagogical level and a topic of the domain very specific (“Reading portfolio for a Persian civilization course in graduate level”, “Reading portfolio of the discovery of Persian literature for adults”, etc.);

2/ The narrative course: publication that provides “reasoned” courses (chronologically, thematically, etc) through a collection of video sequences coming from various video clips;

3/ The virtual documentary: publication that provides a linear reading of a film composed of sequences, selected from various video clips, following the cutting principles of documentaries;

4/ The bilingual folder: publication adapted to the exploitation of the audiovisual document for the learning of foreign languages;

4.3 Specialized Access

Beyond the access to publications using common search criterions (such as main topics, authors, languages, etc.), the administrator of the portal can elaborate new sections by himself, by selecting his own search criterions. These sections are automatically updated after each new publication, and constitute audiovisual “virtual cuttings”, or guided navigation courses (for a pedagogical goal, for example) about very specific topics. Here are some examples of templates developed for ASA-SHS Project:

- Selection of video sequences by *knowledge domain* (“the French writers in the 19th century”, “the german literature in the 16th century”, etc.);
- The *video-lexicon*, access that enables to display every sequence dealing with a particular term (For example, every sequence dealing with the “One Thousand and One Night” tale) ;
- Access to audiovisual resources via *chronological and thematic friezes* (similar to the thematic-temporal friezes used in schoolbooks) ;
- Access to audiovisual resources via *geolocalisation of the content*.

5 Conclusion

The project has finalized very advanced achievements in the fields of ontology design and media description. The developed architecture already followed - and reached - several objectives:

- Upgrade the existing environment and tools developed in previous contexts (ANR Project SAPHIR, European Project Logos)
- Base the architecture on the publishing features we want to develop (ASA-SHS is a content project)
- Develop a system that could be exploited in different contexts (of knowledge domains, institutions, projects, etc.) and where developed ontologies could be reusable.

Thus, the main objective of the project – providing specialized publications – is still under development (“*Semiosphere*”). However, we are very optimistic about future results.

Finally, the weakness of our architecture is not to follow any existing standard. We know how we want to solve this issue (using data converters) and important development efforts need to be done.

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Ktisis: Building an Open Access Institutional and Cultural Repository

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Abstract. The unique value of cultural heritage has long been recognized together with the need for accurate and detailed information in order to preserve and manage cultural heritage material. Any organization whose mission includes promoting access to information is aware of the value of digital collections. For the last few years, digital technology has become very familiar in cultural organizations, providing enhanced access to the content. This paper gives information about Ktisis (<http://ktisis.cut.ac.cy>), the institutional repository of the Cyprus University of Technology (CUT). Ktisis was developed by the Library and Information Services of CUT. The paper reflects on the technical issues that the Library had to face in the preparation of this project and the strategy that had to be defined in order to tackle them. Such issues, among others, include the file and metadata format, the design and implementation software, etc.

Keywords: Open source software, institutional repository, intellectual rights, open access, cultural.

1 Introduction

As the Information Society is evolving in a very fast manner, the technological growth plays an important part in various sectors of the social life, one of which is culture. The cultural diversity of the existing material and the disposal for the exploitation of its value, in combination with the requirement to preserve the original work, constitute the motivation for many institutions to work on projects in order to digitize content of cultural heritage.

Since the early 1990s libraries have worked on digitization projects to provide access to and to preserve unique materials in their collections. These collections are accessible in an enhanced format that allows searching and browsing via the World Wide Web. Preservation of the original content and wide access to researchers and the public are the major reasons that libraries are undertaking digitization projects. Through digitization, the library is able to provide access to all sorts of materials – text, photographs, manuscripts, audio, and moving image materials. Digitization also allows for the preservation of rare, fragile, and unique materials. Another benefit of digitization is that it raises the profile of the institution as user's worldwide access its collections remotely.

An important aspect of a digital library involves handling intellectual property rights. When libraries undertake a digitization project, they need to take into consideration whether or not the material to be digitized is protected by copyright law, or whether it is in the public domain.

Cyprus has a rich cultural heritage in the form of monuments, buildings, paintings, manuscripts, coins, etc. Most of these items are publicly available at museums or archaeological sites. However, there are many private collections of important items that are in danger of being damaged or lost. Examples of such items are private collections of old photographs, volumes of newspapers or magazines that are no longer published and whose content is historical or can be considered as a cultural treasure, etc.

In this manner, the Library and Information Services at the Cyprus University of Technology has defined that one of its major priorities is to collect, disseminate and preserve cultural heritage and to contribute to the cultural evolution of Cyprus. Based on this priority, the Library has designed and developed the first institutional repository in Cyprus, named “Ktisis”.

2 The Ktisis Project

Ktisis is the institutional repository created by the Library and Information Services at the Cyprus University of Technology. Ktisis’s main purpose is to collect and preserve the products of the research of the academic staff and researchers of the university and also to collect, digitize and disseminate cultural content.

One of the main priorities of the Library was to define a strategy for the collection and archiving of cultural heritage material (old photographs, newspapers etc). The objective of this project is to fulfill the Library’s mission for collecting, disseminating and preserving cultural heritage.

When Ktisis was at the designing stage, the Library defined the set of goals that Ktisis needed to achieve. These goals were:

- To locate and archive together cultural heritage items from private collections.
- To guarantee long-term preservation and access to the data.
- To promote interest and involvement in the digitization process and preservation of cultural heritage.
- To promote open access at the Cyprus University of Technology.

In order to fulfill the task, Ktisis needed to accomplish these goals by organizing the data in an effective and coherent representation providing easy access to the public.

Ktisis is a member of a world wide system of open access institutional repositories, participating actively in the new shaped model of scientific communication. Currently Ktisis provides its metadata as a data provider applying the OAI-PMH protocol of metadata harvesting to the following service providers: OAIster, OpenDoar, Openarchives.gr, Driver, Openarchives.eu, Scientific Commons, University of Illinois Data Provider.

2.1 Data Selection

Considering the huge volume and heterogeneity of information on the web, the selection and evaluation of the material to be digitized is one of the most difficult tasks when setting up a digital library. The selection of the material for a digital repository involves handling intellectual property rights, legal issues and copyright.

The Library and Information Services has collaborated with the Patticheio Historical Archive Museum and Centre of Studies for the digitization and archiving of cultural heritage material belonging to the Centre.

The Library has also collaborated with the Cyprus Federation of Amateur Track and Field Athletics for the digitization of a collection of photographs. In addition to that, the Library is in contact with various other organizations or owners of private collections in order to review and record the existing material in order to include it in Ktisis.

2.2 Software Selection

Following the directions of DRIVER (Digital Repository Infrastructure Vision for European Research, (<http://www.driver-repository.eu>), the Library and Information Services decided to set up Ktisis using the open source software DSpace (<http://www.dspace.org>), an open source software developed by the MIT Libraries and Hewlett-Packard Company that enables open sharing of content.

DSpace follows the national standards such as the Dublin Core (<http://www.dublicore.org>) and is compatible with the OAI-MPH protocol of metadata harvesting. It enables capturing the data in any digital format – text, video, audio, and data files. DSpace indexes the digital content, so users can search and retrieve the material. DSpace distributes the digital content over the World Wide Web and it preserves the material over the long term.

The long term preservation facility is supported by using three types of data formats: supported, known and unsupported types. For all three types, DSpace does bit preservation, i.e. the preserved file remains exactly the same over time, and not a single bit is changed. For supported types, DSpace does functional preservation as well. The file changes over time so that the material can be immediately usable in the same way it was originally, while the physical media and digital formats change.

DSpace is a community-based, open source software platform that can be downloaded free of charge and used to create a digital repository. Organizations and institutions can more easily share and preserve their scholarly collections with an archiving system that stores digital representations of books, theses, 3-D digital scans of objects, photographs, film, video, research data sets and other forms of content.

Because DSpace repositories are internet-based, it is easy for users to deposit content and browse collections from anywhere in the world. Materials in DSpace repositories are distributed through the Internet and gain exposure through search engines, such as Google. These same items are permanently stored in a non-proprietary format, so researchers can continue to access its contents for decades to come.

2.3 Technical Issues

In a digitization project, even minor decisions may have a potentially large future impact. At the beginning of the project, one of the first challenges was to determine the future size of the digital repository. In order to do that we had to count the amount of documents we had to digitize, to calculate the amount of space they will need at the host server and estimate the data scalability for the following years. After completing this demanding process we realized that we only have sufficient data to make rough estimations. There was no way to predict what kind of material will come into our hands in the future for digitization and preservation in Ktisis.

Ktisis is covering a wide range of originals: newspapers, journals, photographs, etc. The Library is trying to digitize these items in high quality, with 24 bits in colour depth and resolutions from 300 to 600 dots per inch (dpi). These images are registered in JPG format with sizes ranging between 30 and 800 KB.

2.4 Data Processing

Using the appropriate digitization equipment that complies with the materials being digitized is essential for a successful digitization project. Therefore the Library has been equipped with a high resolution scanner suitable for scanning photos and textual material. The scanned images are stored in the JPG image file format. Then the items go through a watermarking procedure in order to protect them and secure them from unauthorized use.

2.5 Ktisis Data Organization

After the items have been scanned and stored in a JPG format, they need to be submitted to Ktisis. The DSpace content is organized around communities which can correspond to administrative entities such as schools, departments, labs and research centers, or digital collections. Within each community there can be an unlimited number of sub-communities and an unlimited number of collections. Each collection may contain an unlimited number of items.

The Ktisis content is organized in two communities, the Academic Publications containing the produce of the academic and research activity of the members of the university, and the Digital Collection containing the digital heritage material that this paper focuses on.

Currently, the Digital Collections community consists of three collections:

- “Satiriki epitheorisi”, containing approximately 2800 items (number increases daily as new items are added continuously). This collection contains scanned images of caricatures from the cartoon newspaper “Satiriki Epitheorisi” ranging between 1964 and 1985.
- Photos from the Ports of Cyprus, containing 163 photos. This collection includes photographs taken during the construction of the Famagusta port during the period 1871-1933. The documentation took place in collaboration with the Patticheio Historical Archive Museum and Centre of Studies.

- Photos of Olympia Gymnastics sports club, containing 202 photos. The Olympic Gymnastics Sports Club is the oldest athletic club of Cyprus and the second oldest in the Greek area after the Panellinios Sports club. This collection contains photographs from the Cyprus Track and Athletics games. The whole history of the Cyprus track athletics can be seen through this collection. The photographs were taken from the Cyprus Federation of Amateur Track and Field Athletics photo album “Golden Cyprus Winners” as well as from the photographic archive of the Association of Veteran Track Athletes of Limassol. The documentation of the material was accomplished using the album “Golden Cyprus Winners”.

2.6 Data Submission and Registration

The stage of data submission and registration comprises mainly of the creation and registration of the metadata for the resources, and the submission of the resources to the repository. All the items submitted to the repository are structured according to the Dublin Core metadata schema.

The Dublin Core set of metadata elements provides a small and fundamental group of text elements through which most resources can be described and catalogued. Using only 15 base text fields, a Dublin Core metadata record can describe physical resources such as books, digital materials such as video, sound, image, or text files, and composite media like web pages. Metadata records based on Dublin Core are intended to be used for cross-domain information resource description and have become standard in the fields of Library and Information Science and Computer Science. Implementations of Dublin Core typically make use of XML.

DSpace is installed and configured to use the Dublin Core metadata schema by default. Dublin Core is made up of elements, and qualifiers. The Dublin Core basic elements can be seen in Table 1.

Table 1. The Dublin core basic elements

TITLE	The name given to the resource by the CREATOR or PUBLISHER.
CREATOR	The person(s) or organization(s) primarily responsible for the intellectual content of the resource; the author.
SUBJECT	The topic of the resource; also keywords, phrases or classification descriptors that describe the subject or content of the resource.
DESCRIPTION	A textual description of the content of the resource, including abstracts in the case of document-like objects; also may be a content description in the case of visual resources.
PUBLISHER	The entity responsible for making the resource available in its present form, such as a publisher, university department or corporate entity.

Table 1. (*Continued*)

CONTRIBUTORS	Person(s) or organization(s) in addition to those specified in the CREATOR element, who have made significant intellectual contributions to the resource but on a secondary basis.
DATE	The date the resource was made available in its present form.
TYPE	The resource type, such as home page, novel, poem, working paper, technical report, essay or dictionary. It is expected that TYPE will be chosen from an enumerated list of types.
FORMAT	The data representation of the resource, such as text/html, ASCII, Postscript file, executable application or JPG image. FORMAT will be assigned from enumerated lists such as registered Internet Media Types (MIME types). MIME types are defined according to the RFC2046 standard.
IDENTIFIER	A string or number used to uniquely identify the resource. Examples from networked resources include URLs and URNs (when implemented).
SOURCE	The work, either print or electronic, from which the resource is delivered (if applicable).
LANGUAGE	The language(s) of the intellectual content of the resource.
RELATION	The relationship to other resources. Formal specification of RELATION is currently under development.
COVERAGE	The spatial locations and temporal duration characteristics of the resource. Formal specification of COVERAGE is also now being developed.
RIGHTS MANAGEMENT	A link (URL or other suitable URI as appropriate) to a copyright notice, a rights-management statement or perhaps a server that would provide such information in a dynamic way.

DSpace provides the functionality to create different Dublin Core metadata schemas according to the type of the items belonging to a collection. For example, in the case of Ktisis, the metadata describing a collection of photographs is different to the metadata describing a collection of PhD theses.

2.7 Access and Intellectual Rights

Anyone using the internet can access and view the contents of Ktisis without any restrictions. The users can find and retrieve information from the repository easy and fast as Ktisis supports interoperability providing access via multiple search engines and other discovery tools. However, due to copyright issues the items cannot be published or reproduced without the written consent of the owner.

Since its operation, Ktisis provides the capability to choose and apply one of the available Creative Commons licenses. Using the Creative Commons licenses is not obligatory. However, the option to use them is offered in order to be able to define in an easy way the rights that the owner of the item being submitted keeps and the rights that the owner discharges for the use of other creators. A Creative Commons license is a simple way to encourage others to share and reuse your digital content.

Our experience in using the Creative Commons licensing schemes so far has shown that if someone is publishing material of any variety on the web and is interested in spreading this work, then licensing this work under Creative Commons is an effective action as it actively encourages sharing the work with permission and attribution.

Also Creative Commons licenses bridge the gap between full copyright and the public domain, moving content from “all rights reserved” to “some rights reserved.” Creative Commons licenses are not a replacement for copyright; rather, they allow you to modify your copyright terms so your work can be shared and reproduced legally. Additionally, everyone can benefit from the Creative Commons as adding such a license to your work can be seen as a marketing tool. Releasing content under a Creative Commons license gives the content creator full control over how the owner would like his/hers content attributed.

In a digital repository it is required that the rights of the creators are being defined precisely, together with the user rights. This information is precisely defined in the Creative Commons licenses. Currently, there has not been any work on adjusting the Creative Commons licenses for the Cyprus law, so Ktisis uses the English version instead. The Library and Information Services has been in contact with the relevant team of Creative Commons in order to start the procedure of implementing the Cypriot version of the Creative Commons licenses. This procedure is still at the early stages.

The licensing procedure in Ktisis consists of two steps: the first step involves the Creative Commons licenses, and the second involves the Library’s license of submission and dissemination.

When submitting an item and before completing the submission procedure, the user can choose whether he/she wishes to declare the rights of the item being submitted. If the user wishes to use the Creative Commons license, then Ktisis connects with the Creative Commons website. The choices offered at this stage involve the definition of whether the creator or owner of the item allows the commercial use of the item or not, and also whether the owner/creator allows modifications. Then, the available Creative Commons are being displayed where the user is prompted choose one of them.

2.8 Promotion of Open Access

Ktisis was developed as part of the Library’s mission to promote open access at the Cyprus University of Technology. The main reason for universities to have institutional repositories is to enhance the visibility, access and impact of the research product of the university.

Researchers can be actively involved in the promotion of open access by submitting their articles in Open Access journals. Academics can also be more involved in the promotion of Open Access by educating the next generation of scientists in open access. They have to make sure that the new researchers understand the issues of open access and that it increases the impact of research articles.

2.9 Statistics of Use

The Ktisis access statistics show that there is a continuous interest in the content with users visiting Ktisis from all over the world. Analytically, approximately 20000 visitors visited Ktisis in the year 2009. The average number of visitors per month is 1750 from which the 24% are returning visitors.

Approximately 1300 visitors accessed Ktisis directly, 5000 through referring sites and the rest of the visitors found Ktisis through search engines. Ktisis's visitors came from countries such as Greece, Cyprus, the United States, the United Kingdom, India, Germany, Canada, Australia, China, Iran, etc.

2.10 Future Work

As mentioned before, one of the Library's goals is to promote interest and involvement in the digitization process and preservation of cultural heritage. Therefore the Library aims to contribute to the KYPRIANA program(<http://www.kypriana.eu/>). This program is collaboration between various Cyprus organizations in order to contribute in a coordinated way in the growth of the EUROPEANA (www.europeana.eu) project. KYPRIANA aims to become the digital library of Cyprus.

Ktisis has been created using the open source software DSpace. The default installation of DSpace gives the capability to export the metadata in the Dublin Core standard using the OAI-PMH protocol. The problem is that these data cannot be imported into Europeana as Europeana does not support the Dublin core standard, but the European Semantic Elements (ESE), an application profile based on the Dublin Core. The last year a lot of work has been done in Greece in the basis of the program EuropeanLocal in order to overcome this problem. The outcome of this work was the creation of a DSpace plugin which has been created and is available to use free of charge in DSpace installations. The Library aims to apply this plugin into the Ktisis installation making the Ktisis data compatible to the Europeana requirements.

2.11 Lessons Learnt

Today Libraries around the world are deeply involved in the task of preserving the intellectual and cultural heritage of their countries. The Library and Information Services of the Cyprus University of Technology is a pioneer in this field in Cyprus being the very first organization that has created an institutional repository.

The barriers that have come across the Library's work during the development of Ktisis have led the team to infer a number of lessons learnt that may be useful to others. First, we have realized that building an institutional repository requires engaging people with different skills and knowledge in the areas of project management, technology, cataloguing, metadata, etc. Additionally, the development of a repository is a procedure that requires a lot of time. The staff working on the development needs to have a balanced workload in order to reach the short and long term goals of the project. Libraries with limited resources need to be creative and persistent when creating a repository as there are many difficulties in the process.

Institutional repositories are still relevantly new but a number of important benefits have already become apparent. First of all, they support the open access movement. They provide a specialized information service by giving access to the academic and

research work of the university and to the digital collections of cultural heritage material that the Library has digitized. Today institutional repositories address a very strong need in the academic world and therefore there will be a steady growth of repositories globally.

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Realization of a Cartographic GIS for the Filing and Management of the Archaeological Excavations in the Nelson's Island

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Abstract. The island of Nelson is situated around 7-8 miles far from the Egyptian Mediterranean coast, and about 25 km far from Alexandria of Egypt. It has small size, since it doesn't currently overcome the 350 m², even if in the antiquity it was greater: geologic phenomena and activity of cave sensibly reduced the emerged part of it. Campaigns of excavation were carried on that have brought to light important rests related to a fortification and to a military installation, inscriptions of Greek and Byzantine epoch, enormous complexes for the water restocking and a necropolis of late epoch. In the circle of the collaboration in the research CMAIA the geodetic and topographic survey of the island and of the principal structures of archaeological interest are realized. The activities of excavation have not always allowed a perfect synergy with the operations of survey. Nevertheless, the collected results have been integrated with paper maps compiled by draftsmen present on site during the phases of excavation. The activity of survey has been finalized to the cartographic rebuilding of the island and subsequently to the georeferencing of all the findings both through the direct survey and through the integration of the supplied images. An information system has been compiled (database and GIS), once seen the wide massive structure of data and the difficulties of interventions on field; it led to an easier management and cataloguing of the operations of excavation and survey, as well as the accomplishment of an integrated archive of consultation and management of the archaeological, topographic, historical and documentary data.

Keywords: Archaeological site, Map, DTM, Reference systems, GPS, Georeferencing, Data base, GIS.

1 The Archaeological Excavations on the Canopo's Island

1.1 Introduction

The project aims at either preserving the safety of existing and recently discovered documentation and its historical knowledge, or giving a chance to reconstruct the archaeological richness of the Canopo island. The diachronic reconstruction has been accomplished by means of several interconnected activities as archaeological reconnaissance, cartography, analysis of archaeological relics and of historical, epigraphic and iconographic documents. By means of some territorial and archaeological surveys, a

cartographic documentation of the topographic development of the island has been edited. Integrated methods of geodetic and topographic detection have been employed. Starting from a GPS based method, detailed views of the discovered archaeological sites have been finally carried out through a classical topographic survey and the georeferencing of the pictures provided by the archaeologists. The availability of high quality digital cameras, together with advanced software for calibration and production of photogrammetric pictures, allowed to gain a product of good quality. This is why low cost techniques of survey have been employed, which combine the classical topographic instruments with amateur cameras. Obviously, even if cost is lower, the overall quality of the final result is lower too. For Abuquir site the activity has been carried on following this method basically for two reasons: to work with the aforementioned instruments (if possible) and to supply the archaeologists with an easy-to-use tool. Collecting digital data to be examined both real-time and during post processing and analysis required an ad hoc information system. The method we have adopted is based on building a GIS database which is made of two modules: the former is useful for input, displaying, and graphical querying, and is managed by the software ArcGIS; the latter is an ACCESS database of alphanumeric data. The two modules are linked via SQL connections. In order to get a really profitable system to manage the great mass of records given by the archaeological inspection, which could be also capable of improving the knowledge, the aspects we have dealt with the greatest care are: to create an open architecture, which is easy to be integrated with the novel kind of information raising up from the research; setting a correct level of detail in the treatment of each class of data, combining the needs of specific insights on particular aspects of a research project with the criteria necessary for agility successful use of the data; the possibility to have a differentiated usage of depending on the goals of the project and user's computer skills. Under a merely technical point of view, a great attention was paid to the user interface in the development of the database for managing archaeological data.

1.2 The Archaeological Excavations

The island of Nelson, although small, is covered by ruins of tombs, houses, big cisterns and monumental buildings. No scientific excavation has been carried out on the island before 1997, due to the huge natural and bureaucratic difficulties that the excavations involve. On the peak of the oriental promontory of the island, at around 15 m above sea level., signs of an Hellenistic installation of the end of the 4th century BC have been recovered, constituted by a quadrangular building with a side that maybe was about 40 m long at its origin (Fig. 1).

The mighty stone boundaries of the structure, of which only the foundations and some axes remain today, are 1m thick and they are made with big blocks of local sandstone. The plan of the building and its strategic position make us think of it as a structure realized for practical purposes, as for instance a strengthened defence finalised to the control of the naval traffic to the canopic mouth of the Nile. Along the slope that descends gradually towards the sea, the rests of poor houses, maybe belonged to people preceded to the operation of the neighbour structure on the promontory have been brought to light. It is possible therefore that the island of Canopo has lodged a military garrison in defence of the Alexandrine coast. In the western side of



Fig. 1. Settlement of the 4th century BC

the island several complexes of hydraulic structures have been situated for the collection of the rain water. In this area between 1998 and 2000 three great joined and interconnected rectangular cisterns were found. A further survey made in the centre of the island has shown the existence of a tomb hypogeum room entirely excavated in the friable local rock. The continuous erosion which the southern side of the falesa of the island is submitted to, as well as the scour due to the rains, has shown a collective tomb to precipice on the falesa, where many Egyptian mummies were found (Fig. 2).

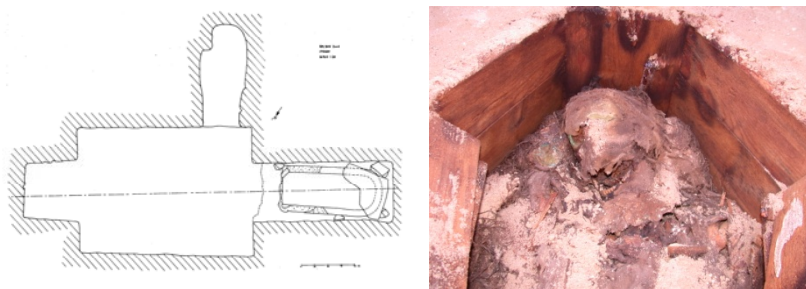


Fig. 2. Sketch of the pharaonic tomb and an Egyptian mummy

1.3 The GPS Survey

The topographic survey of the Nelson's island began with the 1997 campaign during which, using the technique of GPS, the surveys of the island and its detail, as well as the survey of some structures of great archaeological interest, were carried out. A point of reference with a relevant presence of monuments has been chosen on the island. Starting from that point, in the campaigns performed between 1997 and 2000 the monumentation has been executed through a metallic datum nailed in the site denominated FERLA that, nevertheless, for the geologic nature of the island has suffered from a macroscopic move. Insofar, the datum, beginning from the 2001 campaign, has again been monumented by placing it on a pre-existing cement building (whose denomination has been

“85402820”). For both the data and in the different epochs of measurement was performed a connection with the vertex of coordinates notes constituted by the permanent station CEALex situated in Alexandria. In 1998, a reference point was installed on the roof of the building where the premises of the CEALex are situated within the heart of Alexandria. After two 24-hours observation sessions, the coordinates were calculated within the global reference system, ITRF (Table 1).

Table 1. ITRF coordinates of permanent station CEALex

Geographic Coordinates			Cartesian Coordinates		
Longitude (°)	Latitude (°)	Elev.(m)	X (m)	Y (m)	Z (m)
29°54'39,56536'	31°11'49,43277'	57,995	4733389.059	2723027,730	3284632,234

Since then, this point has served to link all the archaeological excavations into the one-reference system. At the end of the year 2000, this reference point was turned into a permanent GPS station with an error of about 2~3 mm. Since 1st December 2001, the resultant data have been available for free downloading from the internet, which represents a first example in Egypt (Fig. 3).



Fig. 3. Master Station placed on the reference vertex of the island

The connection between the instituted datum and CEALex has been performed with GPS measures in static modality with session of around 8 hours and interval of acquisition of 15 seconds. Once the coordinates of arrangement of the datum have been resolved, the detail survey of the whole emerged surface and the outline of the coast-line has been implemented with GPS instrumentation and survey in kinematics modality, enclosing the limits of the submerged barrier, with the purpose to get a DTM, with contours representation of the Nelson’s island (Craig, N., 2000). A total of around 3500 points inside the island have been relieved, with pass of around 5 m, whose coordinate have resolved with precision of around 1-2 cm both in planimetry and in quota (Fig. 4).

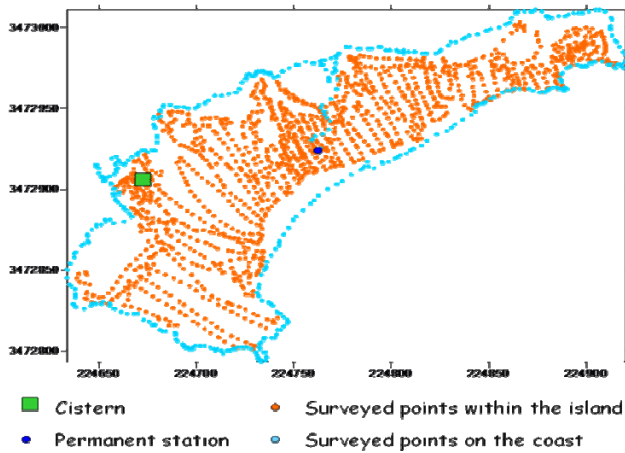


Fig. 4. GPS points Survey

1.4 The Cartography

The existing cartographic representations of the Nelson's island, have demonstrated not to be suitable to constitute a complete support to the archaeological activities, due to the cartographic scale adopted and to the almost exclusively qualitative content, therefore it was necessary to realize ex novo a cartography of detail of the island (Fig. 5). To such purpose the post-verification data of survey have been treated with the two software: Autocad and Surfer. The script Inpoint allows to easily insert a set of points, in the window of the CAD, once their spatial coordinates are known. In this way a file in DXF format has been created with the spatial representation of all the relieved points and of the outline of the coastline. With the Surfer software using the verified data, and using the interpolation method of Natural Neighbour a regular Grid of known points has been built, to square stitch of side 3 m (Hageman, J.B. et al., 2000). The knowledge of the DTM of the island allows to study and to interpret the

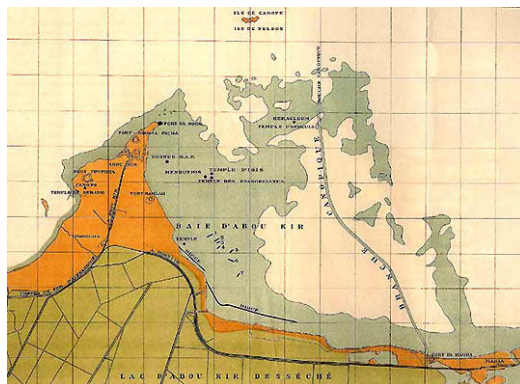


Fig. 5. A part of an already existing map

morphology of the ground to the quest of possible areas of interest for the future excavations; anomalous topographic gradients can, for instance, be located in comparison to the contour, possible indicators of artificial interventions on the ground.

Naturally, to such purpose, it is necessary to choose proper ways of representation of the digital model: the plain map (Contour Map), the three-dimensional one (Wire frame), the shade map (Shaded Relief Map) and the model of surface (Surface), created to represent the island of Nelson, allow to visually interpret the state of the ground in the three dimensions in simple and immediate way (Fig. 6).

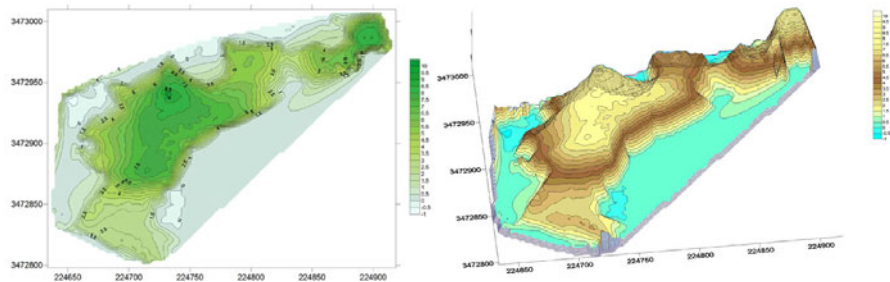


Fig. 6. 3D model of the island

The plain coordinates are expressed in the coordinated UTM-WGS84 system, zone 36, while the quota referred to the level of the sea contextually determined to the surveys. Moreover, the study through time of the coastline will allow to reconstruct, on the base also of the comparison with the historical cartography (if available), the variations in the time of the topography of the emerged part of the island.

1.5 Survey of Archaeological Structures

Using the IRASC software, we effectuated the georeferencing of the sketches of the archaeological excavations of the island of Nelson (Fig. 7), through the individualization

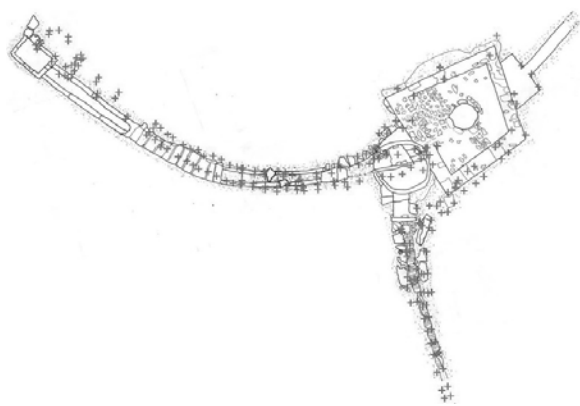


Fig. 7. Overlap of the survey of the main cistern

of a set of coordinates of points acquired on the image (well recognizable and distributed in uniform way) and the relative set of the same relieved points. The georeferencing was obtained using the polynomials of 1st -5^h order individualizing 21 points, among which, a reference vertex; the best results were obtained using the polynomial 1st. The goodness of the taken operations has been estimated both in terms of differences among the coordinates read on the georeferenced image and the coordinates of survey, and from the comparison of the distances among points measured on the image and the same measured in the survey.

The results of the georeferencing of the image are reported in figure 8.

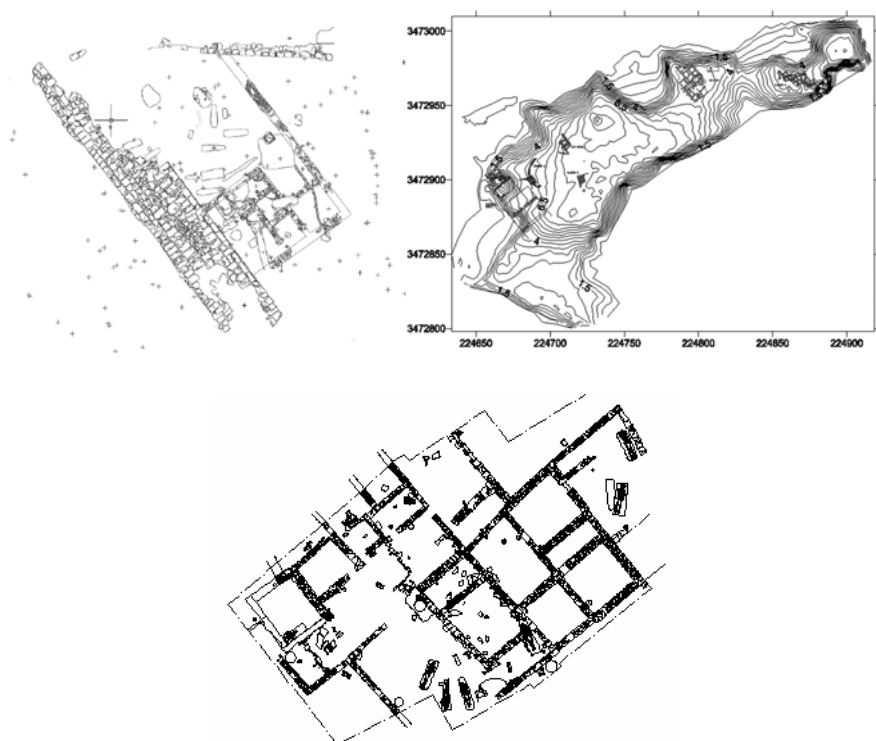


Fig. 8. Georeferencing of the excavations

1.6 The Elaboration and the 3D Analysis

Data acquisition aimed at 3D modeling of layers and structures has been carried on by means of a total electronic station for the measurement of check points, boundaries, and internal points of every US, and with an amateur digital camera (NIKON D40) for zenithal vision (Chiorboli, A., et al., 2005). The calibration of the camera has been performed in the first stage of the post-processing in the Laboratorio di Geomatica. A commercial software, Photomodeler has been used (Gianinetto et al., 2005), which suggests the calibration sequence and calculate the parameters of the

camera. A fixed-lens camera has been used to ensure a constant focal length during the calibration and the photogrammetric surveys. The software performs a calibration based on a grid of 100 points marked on a rigid support. Photomodeler identifies the points automatically, determines their coordinates and builds a 3D model of the shots calculating their parameter too (focal length, coordinate of the primary point XC and YC, sensor size, coefficients Ki of the polynomial of radial reversal).

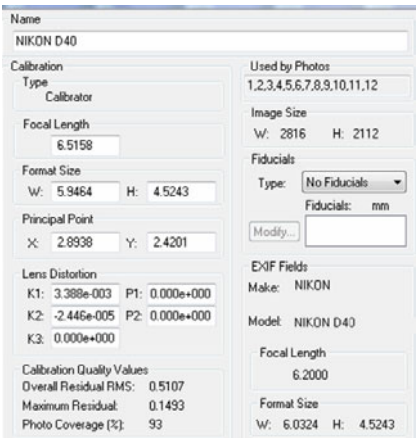


Fig. 9. Parameter of calibration

Once the calibration has been finalized, it was possible to achieve the photogrammetric model through the available digital images and using the GCPs given by topographical survey adding the further geometrical constraint of the distance between two points identified on the model.



Fig. 10. Picture of the wall

Figure 10 shows an example made on a stone wall found during one excavation. 400 topographic points have been identified on the whole surface that has a linear extension of about 100 m.

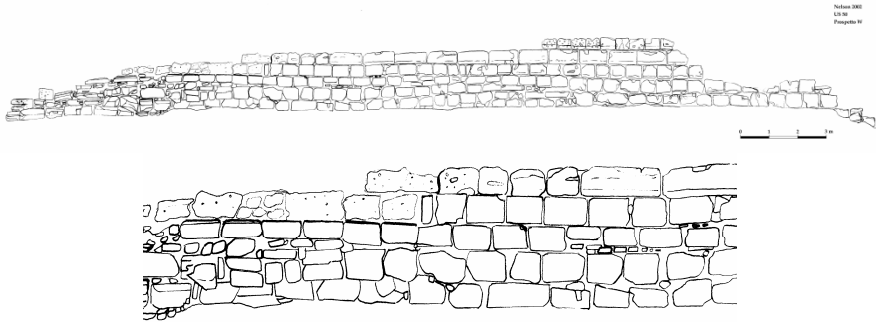


Fig. 11. Prospect W of the Edimon wall

We made such a choice to achieve high accuracy despite not using photogrammetric methods and cameras. Accuracy of the final measurements depends on several factors as the number of available pictures, the angle between them, and the number of points involved in the georeferencing (an increase of which enlarge necessarily the number of CGP which should also be correctly spread on the picture and in the case of a 3D object should also be well representative of picture depth) (Fraser, C. et al., 2006). An accuracy of about some millimeter has been achieved (Brown, D.C., 1971).

All image was orthorectified (Fig. 12).



Fig. 12. Ortophoto of the Edimon wall

2 Geographic Information Systems

2.1 The Nelson's GIS

The objective is to be able to have archive updated for all the activities developed on the field. We needed to create thematic images, fruit of the combination of written, graphic and geographical information, so we used all the potentials offered by the GIS systems. At first a databases is realized, internal to the GIS, customized according to the specific needs.

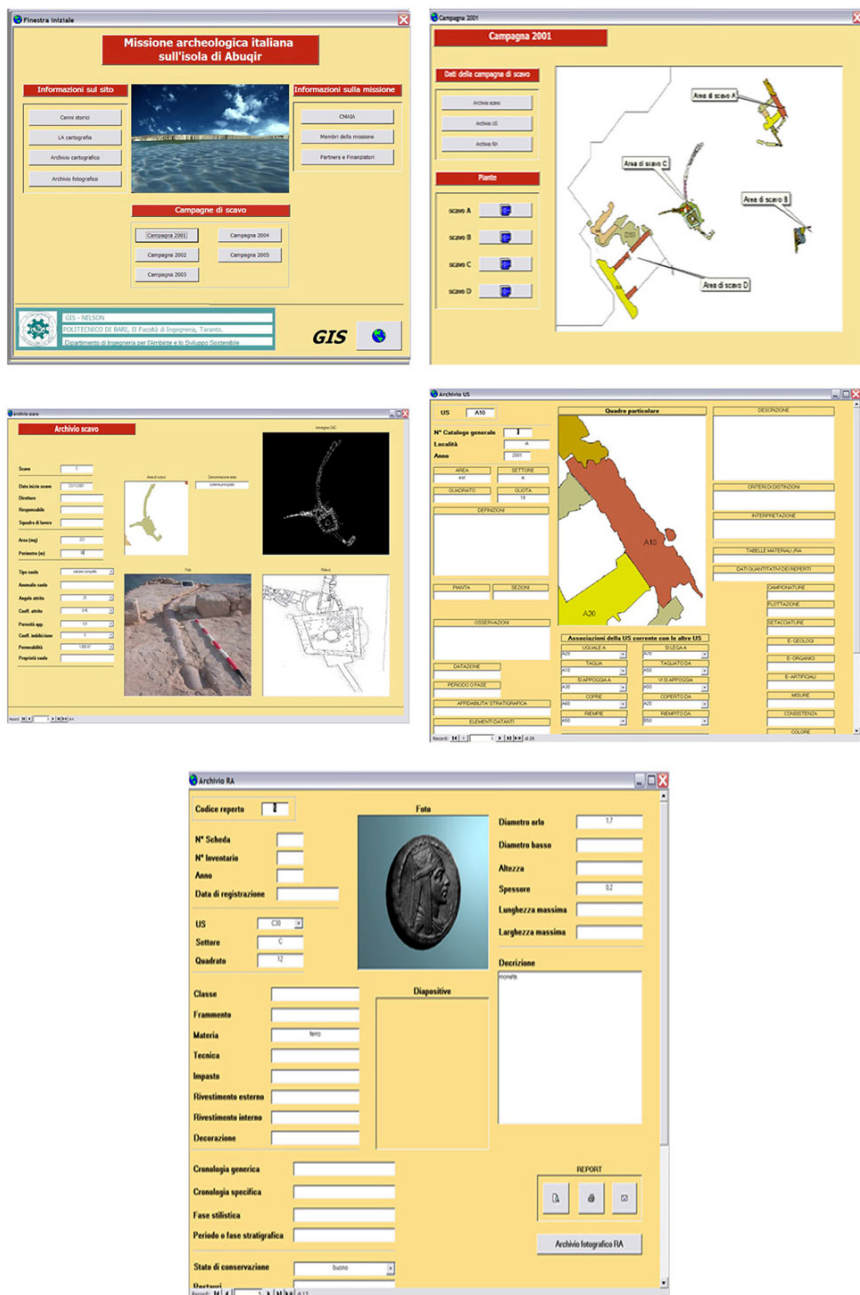


Fig. 13. Database

The informative system has been realized through the building of two modules: one of imission, visualization and graphic-spatial query, managed through the ArcGIS software; the other, connected to the first one through the SQL link, for the management of the alphanumeric data (database), realized in ACCESS. The realization of the GIS was developed through the following steps: the information's coding and structuration of the alphanumeric archive inside a database (DBMS); the formulation of dictionaries and control algorithms to drive the data-entry; the conversion of the plain maps and the single plants of layer in vectorial form, according to levels distinguished for US; the georeferencing of the realized digital cartography and ascription of a numerical code to the graphic objects that define the single unities; the integration of the alphanumeric information and the graphic data through a vectorial GIS engine; the reconstruction of the stratigrafic sediment and of the building structures in 3D, with possibility of spatial analysis and query. The functionality of the system has been guaranteed: by the elaboration of an open and easily integrable architecture (stated the changeable dynamics of the research on the single contexts); by the definition of the degree of detail in the treatment of the single classes data, by conjugating the specific needs of the deepenings on particular aspects with the necessary criterions of agility for a useful fruition of the datum; by the possibility of a diversified use of the solution according to the objectives and of the type of user's computer alphabetization. The database (Fig. 13) allows the access to all the files and to all the information about the Italian archaeological mission to Abuqir, through the initial mask organized in order to allow a rapid access to all the given files, as well as to the information (invariant in comparison to the campaigns of excavation). The relational database is built in such a way as to proceed in the input of the data through the special masks for stratigrafic unity; information of other nature (graphic-geographical) and further details (photographic), as also the other possible cards. From the section "campaigns of excavation" it is possible to access to the files of the single campaigns actually conducted or currently in progress. For each campaign the database is structured in 3 levels: the first, containing the fundamental data inherent the single area of excavation (date of beginning excavation, characteristics of the soil, etc.); the second, related to the stratigrafic data (files US) that reproduces the format of the ministerial ICCD's cards (Central Institute of the Catalog and the Documentation) with the possibility to check the associations between a single US and the others, to define its state of preservation, the dating, the reliability; the last, containing the table of the finds (files RA, ceramic finds, glassy finds, metallic finds, numismatic finds, human osteologic finds, animal osteologic Finds, other finds) with the inherent information, for every recovered find, the classification, the dimensions, the ways of restauration, etc. ICCD and card RA. This relationship happens exactly through the identity code of the US that is used as primary key of connection between the tables, according to a relationship "one to many" are connected to the above database. The cycle is closed with the automatic issuing of a report that, beginning from the introduced data, reassembles the typical card (US e/o RA) we can print and/or send by e-mail (Fig. 14).

[illegible]

Fig. 14. Export window of the US report according to ICCD's standard and e-mail sending

2.2 The GIS Engine

The GIS system with the visualization of the cartography, including the excavations, and with the connection to the Database in SQL link, represents the real engine of the system (Tripcevich, N., 2004). A theme has been realized related to the different stratigraphic unities (US), proceeding to the attribution of a numerical code for the vectorial objects in order to make the direct connection between the tables of the attributes and those of the Database possible (Costantino, D. et al., 2008), by assigning the US relative number, as attribute (Fig. 15).



Fig. 15. GIS Structure



Fig. 15. (Continued)

The second theme is related to the unities of find. Different connections (join and link) between the database and the tables of the attributes of the graphic associated entities, have been finally created, taking advantage of the relationship between identity codes, (Fig. 16).

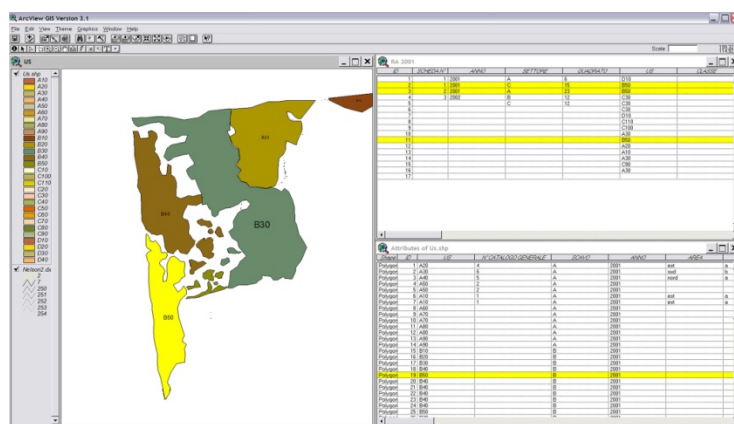


Fig. 16. Example of link between US polygon, RA polygon and relative table of attributes

3 Results

The obtained results have highlighted the efficacy and the applicability of the techniques of topographic and geodetic survey to the goals of a detailed representation of sites of archaeological interest. Of peculiar importance is noticed the methodology of

satellite acquisition (GPS) that has allowed the filing of a considerable massive structure of data with high temporal and spatial frequency to the purpose of the automatic generation of the cartography of the island and the georeferencing of the sketches of excavation. The reliability of this last process has furnished precisions with order of greatness comparable to those resultant from the raster images provided. The cartography datum so obtained results necessary for the development of the future activity both for the geographical analysis of the excavations that for an unequivocal location of the same. The employ of amateur cameras has been really interesting, since it gave nice results and is a low cost and easy to use tool. The growing employ of digital cameras permits, once the calibration has been achieved, to get a good geometric accuracy in restitution phase. The accomplishment of 3D models gives accurate and precise depiction of morphological details, especially in the field of closed-range. The acquisition of information data is easier, cheaper and faster by this way. Photoplanes and ortophotos has shown to be very important in the archaeological documentation. The realized GIS has been structured in order to allow the processing of the data from the site of the harvest to the printing, according to ICCD's standard formats, the filing and the updating of the documentation of excavation in continuous and an easy use, in consideration to the simple user interface. The benefit of the realized tool is useful for those who operates on the field (archaeologist, surveyor, draftsman, topographer, etc.) and to those who intend to complete studies or to have a transversal knowledge of the site.

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Seismic Risk Assessment for Historical Town Centers and Their Surroundings Using Geoinformatics: The Case Study of Paphos, Cyprus

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Abstract. This paper highlights the importance of using Remote Sensing and GIS for assisting the seismic risk assessment for historical town centres in Cyprus. The selected case study is the Paphos town centre including the archaeological area of Nea Paphos. The authors present their proposed methodology for inventory collection, which is based on the integrated use of aerial photos and satellite imagery and the application of digitisation process. A 3D representation of the area using the heights of the buildings and the orthophotos was produced in the ArcGIS software for a more realistic result. The information produced in this pilot project will be used for the seismic risk assessment of the case-study area.

Keywords: seismic risk assessment, historical centers, land use change detection, building inventory.

1 Introduction

The simulation of earthquake losses is the principal basis for the development and implementation of a wide range of planning, zoning, and building ideas that should provide cities with greater safety protection and lower economic losses in the event of a future earthquake that might affect a city. A key and important question that arises in the planning and development of an urban area is: “If earthquakes present a risk of economic loss to area of a city, what are the characteristics and extent of the losses that might occur?”. While seismic hazard studies of urban areas are increasingly more common, it is not so common to apply hazard results to estimate future earthquake losses. Without the estimation of the nature and extent of future losses, it is more difficult to improve emergency relief measures, land use planning, and the seismic provisions of building code in order to mitigate the effects of possible future earthquake losses.

Earthquake loss (risk) assessment consists of three elements: a) an inventory; b) vulnerability relationships; and, c) an earthquake hazard model. Inventory is defined as the geographical distribution and description of things at risk that are included in the study. Vulnerability is defined as the relationships between the hazard assessment

and the inventory that result in losses. Vulnerabilities may be developed for anything at risk (buildings, lifelines, population, etc), although, in practice, vulnerability may be an exceedingly difficult parameter to determine. The earthquake hazard model or models used depends on the kind of risk simulation or assessment required.

One of the most difficult parts of such studies is the determination of the inventory. This is both time consuming and expensive. A number of researchers have studied the possibility of using satellite images [1 and 2] and synthetic aperture radar (SAR) [3 and 4] for the development of inventory of buildings as well as a tool for post-earthquake reconnaissance. Mansouri et al [5] describe such a methodology for the development of a seismic loss model for Tehran, while Chrysostomou et al. [6] for Nicosia, Cyprus.

In this paper the historical town-centre of Paphos in Cyprus is used as a case-study to show how remote sensing techniques can be used to obtain the inventory to be used for the seismic risk assessment of historical centres.

2 Case Study

The historical town centre of Paphos was selected as the case study area for the seismic risk assessment analysis. The historical town centre of Paphos, can be characterized as of equal importance as it is the area that keeps the historical and cultural continuity of the town from the ancient times till today. Paphos historical centre is located in the SW area of Cyprus and it is very near to important archaeological sites (Tombs of the Kings and Nea Paphos) which are listed as UNESCO World's cultural heritage monuments.



Fig. 1. Historical centre of Paphos (NE) and the archaeological sites of Tombs of the Kings and Nea Paphos (W) (background image Google Earth)

Some of the historical buildings of this area are the first Manor houses of Ktima (dated in the early 20th century), Paphos Holy Bishopric (1910 building), Agios Theodoros Metropolitan Church (built in 1896), Ethnographical Museum (built between the late 19th and early 20th century), Town Hall (built in 1955), the Municipal Library (built during the 1940s) a.o.



Fig. 2. The archaeological sites of Tombs of the Kings



Fig. 3. The first Manor houses of Ktima (left) and the Town Hall of Paphos (right)

3 Methodology

For seismic risk assessment analysis, a detail data collection was carried out. This includes cadastral maps, geological maps, earthquake hazard maps, aerial photographs and orthophotos over the area. Moreover a detail database was created in GIS software (ArcGIS 9.3) where the attributes characteristics of each building were recorded. In situ observations were carried out in order to verify these characteristics regarding the buildings (e.g. height of the building). The overall methodology applied for this study is shown in Fig. 4.

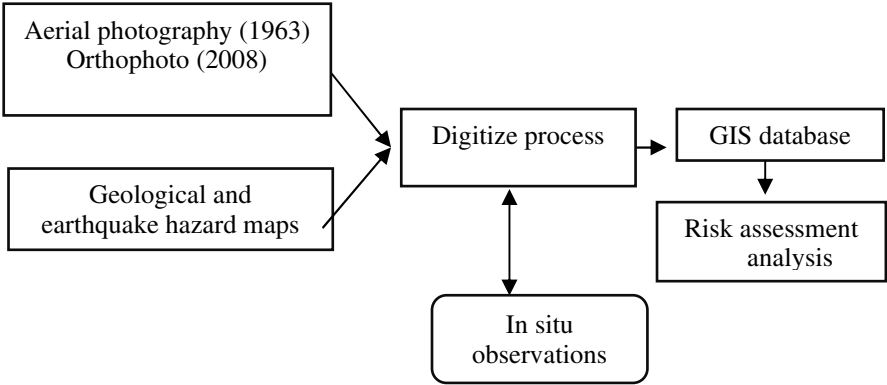


Fig. 4. Methodology applied

4 Data Collection

4.1 Digitization of the Data

In order to observe the changes occurred in the case study area over the last 50 years, nine aerial images (scale 1: 5000) were used dated back to 1963. All these aerial images were georeferenced using an affine polynomial transformation (Fig 5). The digitized procedure was performed in the AutoCAD environment. Distortions due to elevation and geolocation accuracy were considered not be important for the purpose of the study, since the center is located in a flat area. However a more accurate correction of the aerial images is expected to be complete in the future creating an orthophotos mosaic using Digital Elevation Model and Ground Control Points (GCP).

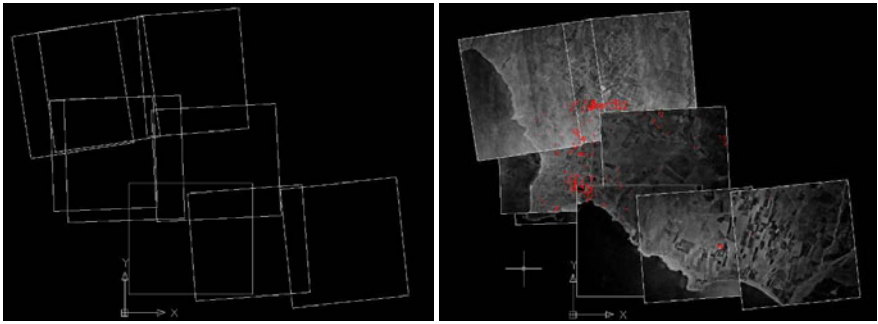


Fig. 5. Georeference of the aerial images (left) and the digitized of the buildings (right)

The same area was digitized using recently obtained orthophotos images of 2008, scale 1: 5000 (Fig. 6 left). The buildings were digitized in AutoCAD software (Fig. 6 right) giving special attention to the area of interest (Fig. 7).



Fig. 6. Orthophoto of the area (left) and digitization procedure of the buildings in the 2008 orthophoto (right)



Fig. 7. Detail digitization procedure of the buildings in the area of interest

Soil types and geological zones were also recorded as it is indicated in Fig. 8. As it was found, the case study area is located in terrace deposits formations while three soil types cover the majority of the area. These are: a) the lithic and epipetric types which cover the coastal area of Paphos (where the Nea Paphos archaeological site is located) and the historical town centre of Paphos, b) the epipetric and leptic-chromic soil type, which cover the southern area of Paphos and c) the calcaric-fluvic and vertic type which are located in the historical town center.



Fig. 8. Geological zones (left) and soil zones (right) in the case study area (polygon)

4.2 GIS Database

Building heights were recorded in a GIS database (ArcGIS 9.3). The data were provided from the Department of Surveys and Cadastral of Cyprus. However in situ observations were carried out in order to complete the entire case study and moreover to verify the data and record any changes. Thematic maps were produced in order to visualize this procedure (Fig. 9).

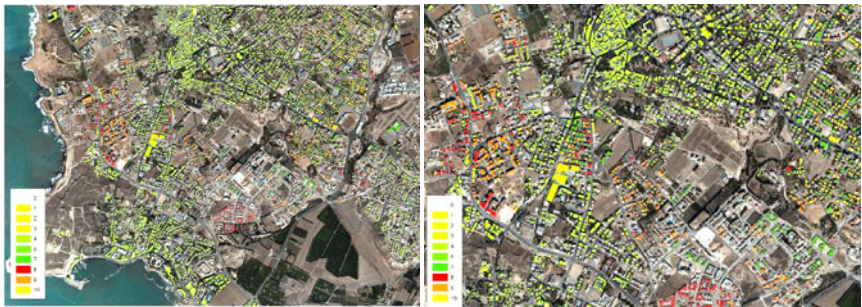


Fig. 9. Buildings height of the area

A 3D representation of the area using the heights of the buildings and the orthophotos was made in the ArcScene software for a more realistic result. For this purpose the orthophotos were draped over the DEM of the area (accuracy $\pm 10\text{m}$) (Fig. 10).



Fig. 10. 3D terrain of the area

The 3D buildings were also categorized according to their height for better interpretation (Fig. 11). The overall area is shown in Fig. 12.



Fig. 11. 3D buildings in the ArcScene software

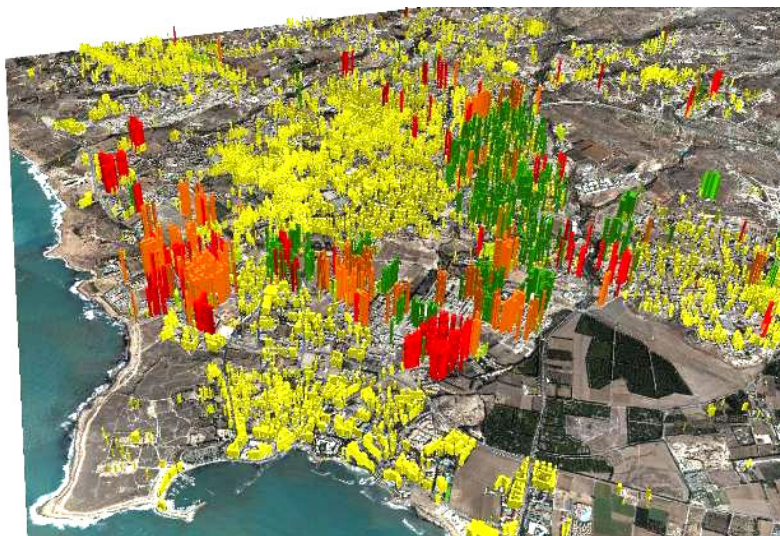


Fig. 12. The overall area in 3D

5 Seismic Risk Assessment

Figs. 11 and 12 give a clear picture of the distribution of the height of the buildings in the area under study. The height of the buildings is one of the main parameters used for the determination of the seismic vulnerability of buildings. Once the location of the various buildings are established in a GIS database, then additional information regarding the buildings that is very useful for the accurate determination of the vulnerability of these structures, such as construction material, type of construction, structural systems, age of the buildings etc., can be assigned. This will assist in the designation of vulnerability relationships as well as site specific earthquake hazard to each building and site. The presence of this information in a GIS database, will give the opportunity for a graphical representation of the data that can be used both for planning as well as earthquake response purposes, and it will be an invaluable tool for the seismic risk assessment of the case-study area.

6 Conclusions

In this paper the methodology of using aerial photography combined with satellite images and a GIS database for the development of the inventory that will be used for the determination of the seismic risk of a case-study is presented. The combination of the above technologies provides a tool that can be used for the accurate documentation of the required inventory in an economic way. The immense graphical capabilities of the GIS database provide the means for continuous build-up of necessary information along with accurate representation of this information, which is imperative for seismic risk analysis. The same tool can be also used for post-earthquake

planning and response. In future work, this tool will be further developed to include the vulnerability and hazard parts that are necessary for the determination of the seismic risk of the case-study area.

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Monitoring Air Pollution in the Vicinity of Cultural Heritage Sites in Cyprus Using Remote Sensing Techniques

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Abstract. Cultural Heritage Sites are in danger of being destroyed due to several factors, such as earthquakes, uncontrolled urbanization and air pollution. The latest, whether it is from industrial, transport or domestic sources, can cause significant degradation and corrosion of cultural monuments. The use of satellite images for monitoring air pollution in different areas has received considerable attention and several related techniques have already been developed. In this study, such techniques are extended to examine air pollution monitoring in areas located in the vicinity of cultural heritage sites in Cyprus. Sun-photometers and Lidar have been used to support the results. The authors incorporate also 3D documentation using a laser scanner for monitoring changes over time. The available technologies and methodologies for digital recording of heritage sites and objects are really promising and the whole heritage community is trying to adopt these approaches for quick, effective, detailed and straightforward 3D reproduction.

Keywords: LIDAR, AOT, Sun-photometers, air quality, cultural heritage, air pollution monitoring.

1 Introduction

Cultural heritage sites are under constant threat from air pollution [1-3]. Europe has one of the largest concentrations of cultural heritage sites in the world [4]. The Mediterranean region is very rich in historical monuments, attracting a significant number of tourists every year, thus the conservation of heritage sites is very important. Studies on air pollution effects on historical monuments in Cyprus have shown high fine and coarse particle concentrations causing particle deposition onto interior vertical surfaces of Asinou church and colour changes perceptible to the human eye within a nine-month period [5]. Assessment of air pollution effects has been performed by different means over the years. In this study, the effects of air pollution on the Medieval Castle of Limassol, which is considered an important cultural heritage site, have been examined using remote sensing techniques.

In order to measure the air pollution in the area, a Lidar and sun-photometer system were established at the Cyprus University of Technology, which is located very near to the study area. Also, an air quality monitoring station that is run by the Department of Labour Inspection (DLI), Ministry of Labour and Social Insurance was available in close proximity.

With the aid of satellite images and ground measurements, the Remote Sensing Laboratory of the Cyprus University of Technology is monitoring pollution at a city-wide level, as well as for a synoptic large cultural area for the cultural heritage sites that are located in urban areas. Satellite remote sensing can be used to assist in air quality monitoring [6-9] and identify the need to protect cultural heritage in urban areas from air pollution. Satellite remote sensing is a valuable tool for assessing and mapping air pollution due to its major benefit of providing complete and synoptic views of large areas in one snap-shot image, on a systematic basis due to the sufficient temporal resolution of various satellite sensors [10-11].

2 The Site

The Medieval Castle, located in the center of Limassol town (Fig. 1), was built in the 14th century on the site of an earlier Byzantine Castle, where Richard the Lionheart, King of England, married Princess Berengaria of Navarre in 1191 and crowned her Queen of England. According to Etienne Lusignan, the original Castle was erected by Guy de Lusignan in 1193 and was surrendered to the Knights of Jerusalem in 1308. Archaeological excavations within the Castle exposed a marble podium from an early Christian basilica and the floor of a Middle Byzantium monument from the 10th or 11th century. In 1373, the Genoese burned down Limassol town after having occupied the Castle. It is likely that the Castle was badly damaged. The Castle was again restored in order to withstand renewed attacks by the Genoese in 1402 and 1408. In 1413, the Castle survived the first attack of the Mamelikes but severe damage resulting from an earthquake led to its capture in 1425 by the Mamelikes in their second attack on the city. At the beginning of the 16th century, extensive reconstruction took place. The gothic arches of the underground chamber and the openings in the side walls can be attributed to this period. The castle is a significant tourist attraction all year round.



Fig. 1. Area of Medieval Castle

3 Methodology

The overall methodology of this paper is shown in Fig 2. The methodology is based on the integration of several tools for assessing the air pollution measurements determined directly from satellite imagery such as Landsat TM or ETM+ and/or MODerate resolution Imaging Spectroradiometer (MODIS) imagery. Such tools are the sun-photometers, Lidar system and air pollution measurements.

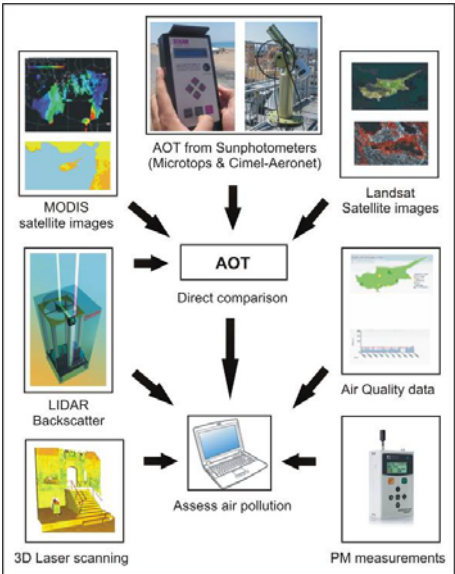


Fig. 2. The methodology applied

3.1 Satellite Based AOT Detection

The use of Earth observation to detect atmospheric pollution in different geographical areas and especially in cities has received considerable attention [6]. All the studies have involved the determination of aerosol optical thickness (AOT) either using indirect methods using Landsat TM and SPOT images or MODIS images in which AOT

is given directly. The superior spatial resolution of Landsat and SPOT enable several researchers to develop a variety of methods. For example, Kaufman et al. [7] developed an algorithm for determining the aerosol optical thickness (using land and water dark targets) from the difference in the upward radiance recorded by the satellite between a clear and a hazy day. This method assumes that the surface reflectance between the clear day and the hazy day images does not change. Sifakis and Deschamps [12] used SPOT images to estimate the distribution of air pollution in the city of Toulouse in France. They developed an equation to calculate the aerosol optical depth difference between one reference image (acquired under clear atmospheric conditions) and a polluted image. Their method was based on the fact that after correction of solar and observation angle variations, the remaining deviation of apparent radiances is due to pollutants. Retalis [8] and Retalis et al. [9] showed that an assessment of the air pollution in Athens could be achieved using the Landsat TM band 1 by correlating the aerosol optical thickness with the acquired air-pollutants. Moreover Hadjimitsis and Clayton [13] developed a method that combines the Darkest Object Subtraction (DOS) principle and the radiative transfer equations for finding the AOT value for Landsat TM bands 1 and 2. Hadjimitsis [14] developed a method to determine the aerosol optical thickness through the application of the contrast tool (maximum contrast value), the radiative transfer calculations and the 'tracking' of the suitable darkest pixel in the scene for Landsat, SPOT and high resolution imagery such as IKONOS and Quickbird. Satellite remote sensing is certainly a valuable tool for assessing and mapping air pollution due to their major benefit of providing complete and synoptic views of large areas in one image on a systematic basis due to the good temporal resolution of various satellite sensors [6]. Aerosol optical thickness (AOT) is considered as the main parameter that is used to assess air pollution.

AOT expresses the degree to which aerosols prevent the transmission of light and comprise an indicative parameter for assessing air pollution in the vicinity of cultural heritage sites. AOT is a measure of aerosol loading in the atmosphere. A higher AOT value indicates higher columnar of aerosol loading and hence lower visibility [15]. MODIS on board the Earth Observing System (EOS) Terra and Aqua satellites [16] is a sensor with the ability to measure the total solar radiance scattered by the atmosphere as well as the sunlight reflected by the Earth's surface and attenuated by atmospheric transmission.

The accuracy of satellite-derived AOT is frequently assessed by comparing satellite based AOT with AERONET (AERosol RObotic NETwork – a network of ground-based sun-photometers) or field based sun-photometer [17-18]. The determination of the AOT from the Landsat TM/ETM+ imagery is based on the use of standard calibration targets defined on the image, preferably dark targets. For every grid (30m × 30m) on the Landsat imagery, the aerosol optical thickness is determined using the radiative transfer equation.

Since MODIS has a sensor with the ability to measure the total solar radiance scattered by the atmosphere as well as the sunlight reflected by the Earth's surface and attenuated by atmospheric transmission, the AOT results found by MODIS were compared with the sun-photometer's AOT results [18]. For the MODIS images, despite its low pixel resolution, aerosol optical thickness values were extracted for the 550 nm band. Based on the fact that a Landsat TM/ETM+ almost covers the whole area of Cyprus with sufficient spatial and temporal resolution, it was considered that such images were the most appropriate to be used for monitoring purposes.

3.2 Sun-photometers

In this study, two different sun-photometers were used to retrieve AOT. The Microtops II (Solar light Company, USA) hand-held sun-photometer measures the attenuation of the direct sunlight and the total transmittance from which AOT of the atmosphere is derived [19]. In order to achieve measurements with higher accuracy, this sun-photometer was mounted on a tripod at the same location on each occasion. The second sun-photometer used was the Cimel sun-photometer which is a multi-channel, automatic sun-sky scanning radiometer that measures the direct solar irradiance and sky radiance at the Earth's surface. The instrument is calibrated under the supervision of the AErosol RObotic NETwork (AERONET) network [20]. Measurements were taken in the visible and near-IR parts of the spectrum to determine atmospheric transmission and scattering properties. The correlation between the two instruments was determined in order to establish the validity of the AOT levels measured by the sun-photometers.

3.3 Lidar

The findings were triangulated using the Lidar system. The Lidar system is a laser radar using electromagnetic radiation 10000 to 100000 times shorter than those used by conventional radars [21]. For this study, the Raymetrics Backscattered Lidar was used, located in the Limassol area near the Medieval Castle. The Lidar is able to provide aerosol or cloud backscatter measurements from a height beginning from 170m to tropopause height. The Lidar emits a collimated laser beam in the atmosphere and then detects the backscattered laser light from atmospheric aerosols and molecules. The Lidar transmits laser pulses at 532 and 1064 nm simultaneously and co-linearly with a repetition rate of 20 Hz. Three channels are detected, with one channel for the wavelength 1064 nm and two channels for 532 nm. The columnar optical depth is determined from sun-photometers at the wavelength of 500nm, while from Lidar and MODIS at 532nm and 550nm respectively.

3.4 $PM_{2.5}/PM_{10}$

Air quality in Cyprus is monitored by a network of nine advanced stations (Fig. 3 and 4) by the Department of Labour Inspection (DLI). These data are recorded hourly and are available on the internet. They have been used for comparison and validation purposes. $PM_{2.5}$ and PM_{10} data were recorded in June 2010, around the Medieval Castle, as shown in Fig. 4, using the Partical Handheld Mass Counter (AEROCET 531), which counts individual particles using scattered laser light and calculates the equivalent mass concentration.

3.5 Comparison of Methods

Comparison between the in-situ measurements taken in the centre of the city and the MODIS and Landsat satellite images allows estimation of the air quality levels throughout the city. The method is based on the principle that any changes between the derived atmospheric path radiances from the satellite imagery can be attributed to varying degrees of scattering and absorption by varying concentrations of aerosols



Fig. 3. Photos of Traffic Station used for monitoring air quality in Cyprus

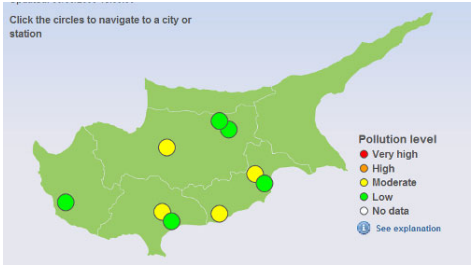


Fig. 4. Direct web-access to retrieve air quality data

(including haze), since molecular scattering is assumed to be constant with time in the same geographical area. The method is applied to the standard calibration targets for determining the atmospheric path radiance in the area under investigation. Indeed, dark and bright objects in the image are selected in the vicinity of cultural heritage sites. Landsat TM satellite image using band 1 is used to identify AOT in a grid format.

3.6 3D Laser scanning

The 3D laser scanner Leica Scan Station C10 was used to document the castle (Fig 5). The specific laser scanner has a maximum scan rate of 50000 points per second, while the accuracy is $\pm 6\text{mm}$ in position (X,Y,Z) at a distance up to 50m. The laser beam diameter is $\pm 7\text{mm}$, while the field of view of the Scan Station is $360^\circ \times 270^\circ$. Moreover, the laser allows acquiring the reflected beam intensity and RGB colours. The castle will be documented every year with the 3D laser scanner in order to compare the results to determine any deterioration caused by air pollution. To establish that the deterioration is a result of air pollution, areas of the castle which show deterioration on the 3D laser scanner will have samples taken to determine the chemical analysis of the surface to establish if the deterioration was caused by air pollution or natural causes. Photographs of the castle were also taken and applied to the 3D laser scanned point cloud.

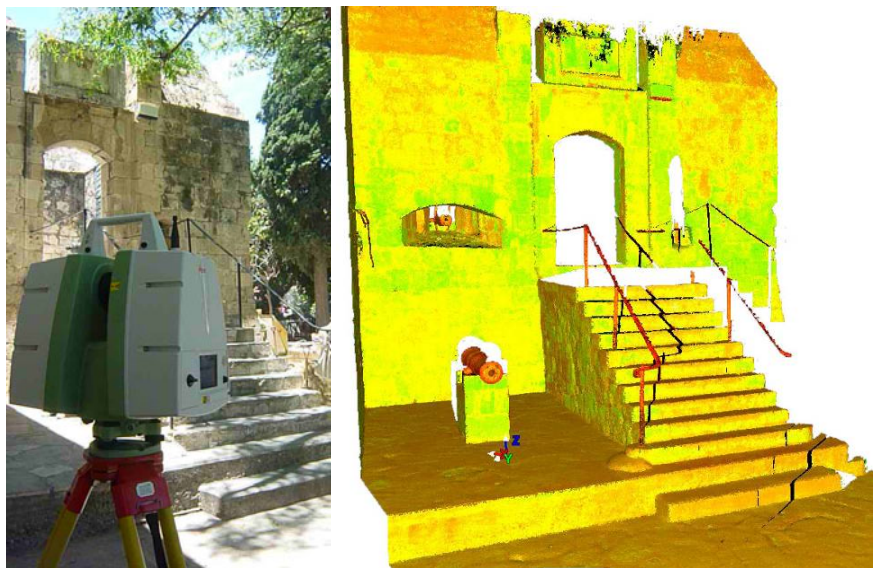


Fig. 5. 3D laser scanning of the Castle (left) and Point cloud generated by 3D laser scanner (right)

4 Results

According to the air quality data provided by the Department of Labour Inspection, the majority of daily air pollution concentration values for PM_{10} exceeded the relevant limit, which is $50 \mu g/m^3$, as prescribed by the European Union (Fig. 6).

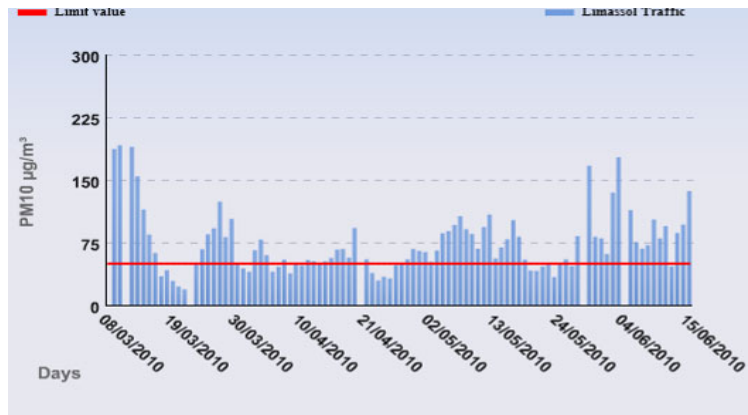


Fig. 6. Daily variance of PM_{10} for the study area (<http://www.airquality.dli.mlsi.gov.cy/>)

The AOT measurements with two sun-photometers, CIMEL and MICROTOSPII were taken adjacent to Medieval Castle (34.675° N, 33.043° E) within 40 minutes of the satellite overpass time on each day with full sunshine during the three month period April to June 2010. The high correlation $r=0.92$, which is derived from the coefficient of determination $R^2=0.84$, between the two sun-photometers (Fig. 7) ensures a high level of confidence in the measurement of AOT.

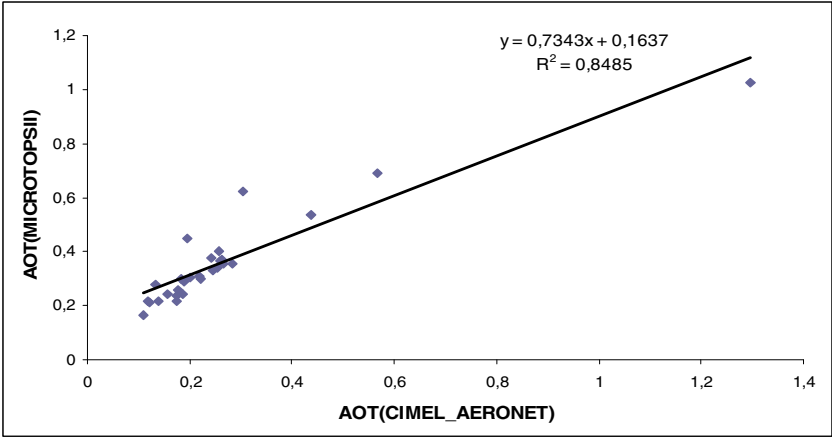


Fig. 7. Sun-photometers AOT correlation

The AOT data retrieved from MODIS and sun-photometer (CIMEL) also provided a high correlation ($r=0.9$, $R^2=0.81$) as shown in Fig. 8.

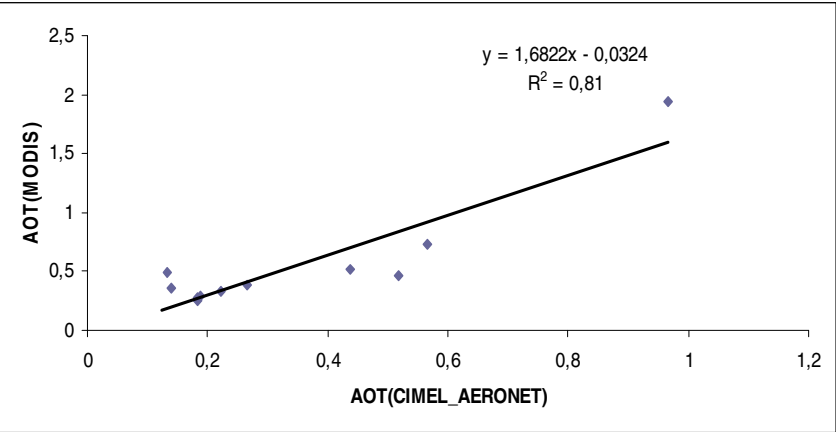


Fig. 8. MODIS and AERONET AOT correlation

Determination of AOT measurements using Landsat images has shown that the centre of Limassol, where the Medieval Castle is located, experiences the highest level of AOT values (Fig. 9).



Fig. 9. The AOT distribution in the Limassol area retrieved from LANDSAT images

A PM₁₀ /PM_{2.5} field measurement in situ campaign has also been carried out in the area of Medieval Castle using a Particle Mass Counter. Especially on 23rd June 2010 it was found that PM₁₀ readings exceeded the limit value (50 µg/m³) for all four locations in Medieval Castle with the greatest value in the South part of the area (Table 1). Concerning the PM_{2.5} data, values remained in low concentrations and only in the South part of the Castle the value was close to the limit value (25 µg/m³).

Table 1. Concentrations (µg/m³) for the study area

Location	Time(UTC)	PM _{2.5}	PM ₁₀
East	9.10	14	239
South	9.15	22	301
West	9.20	11	164
North	9.25	16	247

The Lidar system provides accurately the spatial and temporal evolution of the aerosols within the troposphere. As shown in Fig. 10 and Fig. 11 (which indicate a high aerosol loading), the vertical profile of aerosol backscatter coefficient and the temporal evolution could be viewed up to a height of 4km.

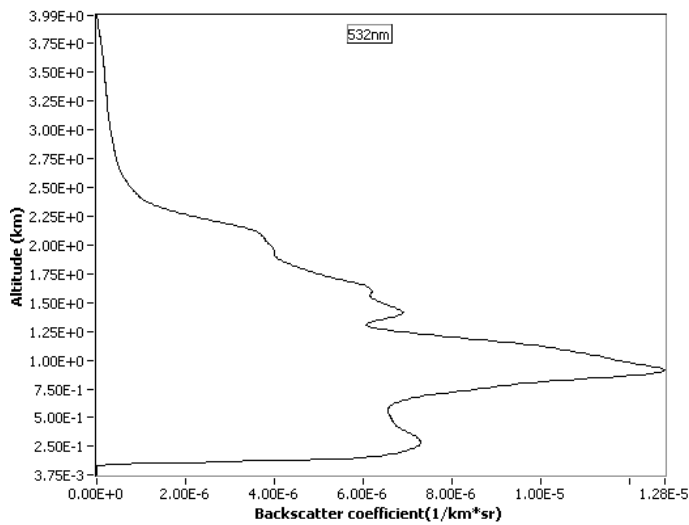


Fig. 10. Vertical distribution of the backscatter coefficient, over the area of Medieval Castle, on the 02/06/2010 (09:00 UTC)

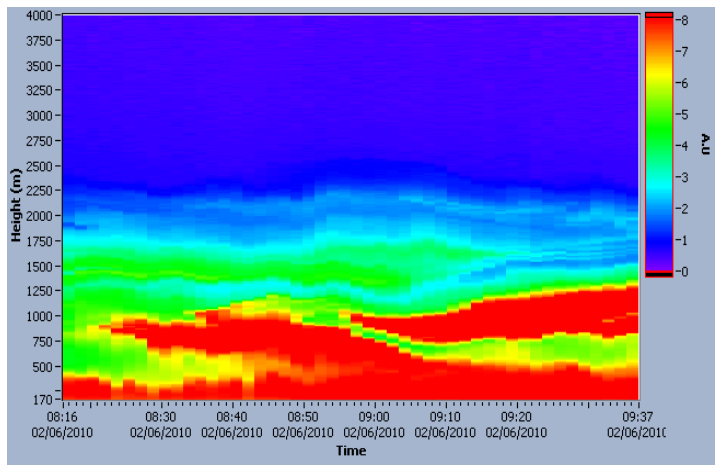


Fig. 11. Temporal evolution of aerosol layer over the area of Medieval Castle, on 02/06/2010 (09:00 UTC)

5 Conclusions

Existing air quality monitoring stations in major cities can provide warning of potential damage to cultural heritage sites, but they typically employ ground-based instrumentation, which restricts the area of land that can be monitored and investigated [22]. Additionally, ground-based monitoring can be expensive, time-consuming and restricts the access of tourists to heritage sites. This paper has shown that satellite

remote sensing can be successfully employed together with ground measurements for the purposes of air pollution monitoring near heritage sites.

Satellite remote sensing has been widely used to improve air quality monitoring in urban areas. It comprises a valuable tool for assessing and mapping air pollution due to its major advantage of providing complete and synoptic views of large areas in one snap-shot image on a systematic basis, due to the sufficient temporal resolution of various satellite sensors.

Results from satellite remote sensing have identified that the centre of Limassol contains high levels of air pollution, with values of AOT higher than other surrounding areas. Further investigation will identify the worst hit areas in terms of air pollution at heritage sites in Cyprus and the variability of AOT values over time.

Systematic monitoring of heritage areas, such as the area of the castle, by using the 3D laser scanner will further assist validation of deterioration possibly caused by air pollution. Thus, chemical analysis of deteriorated surfaces will follow for final verification.

Cyprus has a number of cultural heritage sites that are located in the centre of cities, such as Nea Paphos, Tombs of the Kings, and ancient Kition. Areas under threat from natural disasters or anthropogenic effects can be monitored using remote sensing. Monitoring cultural heritage sites in urban areas can also be extended to other major cities in Cyprus that have cultural heritage sites located in urban areas.

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