EuroMed2010
Digital Heritage

3rd International Conference dedicated on Digital Heritage

Short Papers

Before July, 1974…

After July, 1974…

The Katholikon of the Monastery of Antiphonitis in Kalogrea, Cyprus (16th century)

Don't miss the Hi-*tech*-Story…

8th–13th of November 2010
Limassol, Cyprus

Edited by
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Christ *Antifonitis* near *Kalogrea* in the Kyrenia district in Cyprus is another church, which was built and decorated with wall paintings in approximately 1200 AD. In the early 16th century, the north and south wall of the church proper and the northwestern squinch were decorated with wall paintings from the life of the Virgin, the Stem of Jesse, the Last Judgment and the standing saints, while the cupola was decorated with Christ Pantocrator, the Deesis-Supplication, the Apostles seated on thrones and the Prophets. Unfortunately, after the Turkish invasion in 1974 and the occupation of the area by the Turkish army, the systematic destruction and removal of the wall paintings from the monument began. The faces of Archangels Michael and Gabriel in the conch of the apse were barbarically destroyed, while the wall painting of the Birth of Christ was removed. These wall paintings are dated from the end of the 12th or early in the 13th century. The great wall paintings of the Stem of Jesse and the Last Judgment (early 16th century) were fragmented into small pieces and removed from the south and the north wall on which they were painted. Several *fragments from the wall paintings (in yellow outlined)*, which had been exported by Turkish smugglers to Germany from where they were repatriated, are on display on the second hall of the Byzantine-Museum (BM.321-356) in Nicosia, Cyprus. Others are in Germany and it is hoped they will be returned to Cyprus. When all the pieces which have been found are gathered, an effort will be made to restore these two large wall paintings using different modern applications from the area of Digital Heritage.

Photos: Eliades Ioannis, Curator, Byzantine Museum in Nicosia, Cyprus

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Foreword

We would like to take this opportunity to welcome you all to the 3rd International Euro-Mediterranean Conference (EuroMed 2010) on the historical island of Cyprus.

This volume contains the so-called “short” papers presented at the EuroMed 2010 International Conference held in Limassol, Cyprus, on 8th – 13th of November 2010. The Conference is an effort of several organizations and continues the successful series of EuroMed Conferences, which started in Nicosia, Cyprus in 2006. Since 2006 the EuroMed conference is organized in cooperation with CIPA, which is one of the oldest International Scientific Committees of ICOMOS (The International Council for Monuments and Sites) and was founded in 1968 jointly with ISPRS (International Society for Photogrammetry and Remote Sensing) to facilitate the transfer of technology from measurement sciences into heritage documentation and recording disciplines. CIPA originally stood for the Comité International de Photogrammétrie Architecturale (http://cipa.icomos.org). However, this old and well known name no longer describes the full scope of CIPA activities, therefore CIPA Heritage Documentation was established, which is now an organization that endeavours to transfer technology from measurement and visualisation sciences to the disciplines of Cultural Heritage recording, conservation and documentation. CIPA holds an International Symposium every two years. Accompanying these Symposia, frequent specialist workshops are held, which deal with specific topics.

The focal point of this Conference is Digital Heritage, which all of us involved in the documentation of Cultural Heritage continually strive to implement. The excellent selection of papers published in the Proceedings reflect in the best possible way the benefits of exploiting modern technological advances for the restoration, preservation and e-documentation of any kind of Cultural Heritage. Above all, we should always bear in mind that what we do now may be used by people in another century to repair, rebuild or conserve the buildings, monuments, artefacts and landscapes that seem important. Recent events like earthquakes, tsunamis, volcanic eruptions, fires and insurrection show that we can never be too prepared for damage to, and loss of, the physical and non-tangible elements of our past and in general the Cultural Heritage.
To reach this ambitious goal the topics covered include experiences in the use of innovative recording technologies & methods and how to take best advantage of the results obtained to build up new instruments and improved methodologies for documenting in multimedia form, archiving in Digital Libraries and managing the Cultural Heritage.

Technological advances are very often reported in detail in specialised fora. This volume of proceedings establishes bridges of communication and channels of cooperation between the various disciplines involved in Cultural Heritage. Furthermore, the contributions presented in this conference and included herein can assist all experts involved in the Cultural Heritage area in restoring, renovating, protecting, documenting, archiving, monitoring of the history of humanity in order to secure this information for the years to come. It is evident and clear that a worldwide collaboration in this area will help make our “Hi-tech-Story” accessible to the present and the future.

This important event and the proceedings you are holding in your hands contribute decisively to providing a forum for scientists and professionals to share ideas, experiences, needs and problems.

The papers contained here are shorter in length, but not lower in quality. Authors have chosen to contribute preliminary results of work-in-progress in a shorter form, while mature research is presented in the “full” papers volume in the LNCS Proceeding from Springer Verlag. “Short” papers have been peer-reviewed and due to the great number of submissions, only a small part of them could be accepted and published.

We gratefully acknowledge that this task would not be possible without the support from our paper reviewers, collaborators and sponsors.

Marinos Ioannides, Dieter Fellner, Andreas Georgopoulos and Diofantos Hadjimitsis
November, 2010 – Cyprus

CONTENTS

2D and 3D Data Capture Methodologies and Data Processing in Cultural Heritage

Part I

GEOMETRIC DOCUMENTATION OF HISTORICAL CHURCHES IN CYPRUS USING LASER SCANNER

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KEY WORDS: geometric documentation, laser scanner, 3-D modelling

ABSTRACT: Laser scanners offer a sophisticated alternative to the conventional data collection methods, with very good resolution and accuracy. Cultural heritage sites such as churches are subject not only to natural ageing but also to natural accidents, inappropriate interventions and modifications and vandalism. Therefore, documentation is critical and laser scanner is an ideal tool for such application. This paper explores the effective use of laser scanner technology in three different churches in Cyprus. The laser scanner Leica ScanStation C10 was used for the geometric documentation of facades of historical churches and for frescoes of the 13th century. The data collection of these examples is briefly described as the post processing and the 3D modelling of the data. GIS uses the final geometric documented products for storing and management purposes for any future use by any engineer or archaeologists.

1. INTRODUCTION

Terrestrial laser scanners are increasingly being used for cultural heritage recording, for architectural documentation studies, for research of cultural heritage with photogrammetric methods and for engineering applications that demand high spatial resolution. Due to their high data acquisition rate, relatively high accuracy, and high spatial data density, terrestrial laser scanners (TLS) are being used for such applications. (Lichti, 2004; Ergun, 2010).

The laser time-of-flight method, that will be discuss in this paper, is a robust method, and can provide distance measurements in a range of more than 50m within a centimetre accuracy (Wulf and Wagner, 2003). However it must be emphasized that for the documentation of large objects, architectural mapping, accurate topographic surveys and laser scanning are used along with photogrammetric techniques (Grussenmeyer et al. 2008).

In this way the documentation of Cultural Heritage sites and monuments induces the production of numerous and heterogeneous data. The management of these data is an essential task for the use and the diffusion of the information gathered from the documentation procedure (Meyer et al., 2007). The use of Geographical Information Systems (GIS) in order to store, analyze and maintain cultural heritage datasets is a significant and vital task nowadays (Meyer et al., 2007) Moreover the use of GIS database is ideal in order to combining a 'spatial approach' to heritage preservation (Rüther et al., 2009).

In this paper we present some results from the use of -time of flight- laser scanner for cultural heritage documents in Cyprus. The methodology applied and the preliminary results are discussed while the use of GIS for maintaining the datasets of these documentation is finally briefly presented.

2. CASE STUDIES

Different objects and monuments of cultural heritage were chosen for the aims of the paper. These objects differ not only in size and complexity but also and in other ways such as light conditions. The objects selected can be tabulated into two main categories: monuments and religious frescoes / icons.

2.1 Monuments

One monument in Kouklia region and one in Letybou village were partially scanned. Moreover the ancient church of Saint Theodore in Idalion locality was documented. In Kouklia village the façade of Church of Panagia Katholiki was scanned and the arch in the entrance of the church was also scanned in full 3D. In Letybou village, the bell tower of Church of Saint Kirikos and Ioulitis was also partially scanned.

Church of Panagia Katholiki: Panagia Katholiki is located in the centre of Kouklia village (Figure 1). The church follows the type of a cruciform church and dates to the 12th or 13th century A.D. The western sector was added in the 16th century. The surviving wall-paintings, which decorate the interior of the church, reflect the traditional frescoes of the 15th century.

Figure 1: Church of Panagia Katholiki at Koukla village

* Corresponding author.

2.1.1 Church of Saint Kirikos and Ioulitis: Saint Kirikos and Ioulitis church is a cruciform church with a dome and dates to the 12th century, although many interventions have been made, mainly during the late 15th century (Figure 2). There are few wall paintings from the 12th century, but the majority of them are dated in the 15th century. During a restoration, which took place 10 years ago, some wall paintings were found to have the date of their creation.

The church is stone made and is perfectly restored. It is placed under the surface of the ground, at about 1,5 meters. The yard is relatively big and fenced. On the southeast section the old wall is preserved but on the northwest section there is a baluster. Before the big earthquake of 1954, there was also a large front door with an arch. The bell tower is made of stone and was built in 1950 (http://www.letymbou.org/english/churches.shtm).

Figure 2: The church of Saint Kirikos and Ioulitis in Letymbou village

2.1.2 Church of Saint Theodore: The Church of Saint Theodore is located in the Idalion village, in Nicosia (Figure 3). It is an ancient church, and it located approximately 12m below ground surface. The monument has recently been protected by the Department of Antiquities of Cyprus.

Figure 3: The ancient church of Saint Theodore

2.2 Religious frescoes and icons

The fresco decorating the west part of the Saint Kirikos and Ioulitis's church was scanned. The fresco, of Christ, dates from the 13th century A.D. and it was recently restored (Figure 4).

Figure 4: Fresco in the west part of the church

Moreover another one fresco of Saint Kirikos and Ioulitis was scanned. Finally an icon of Saint Theodore was scanned (Figure 5).

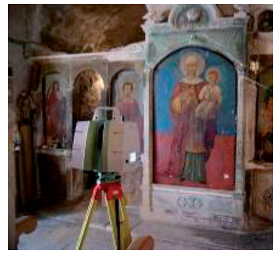


Figure 5: Saint Kirikos and Ioulitis fresco (above) and Saint Theodore icon (down)

3. METHODOLOGY

For recording with laser scanner, the methodology as shown in Figure 6 was applied. The laser scanner ScanStation C10 was used in a local reference system. The necessary analysis and FOV of the scan was selected for each scan station. After the scanning procedure was completed the post-processing of the data was followed. This includes the removal of the noise and the point's clouds registration. Afterwards the modelling of the data was performed.

Moreover a GIS database was produced in order to monitor the documentation procedure. This includes the geographical data such as cadastral maps of Cyprus, location of the monument e.t.c and the attribute table of these monuments regarding the documentation procedure such as the method applied the historical background of the sites etc.

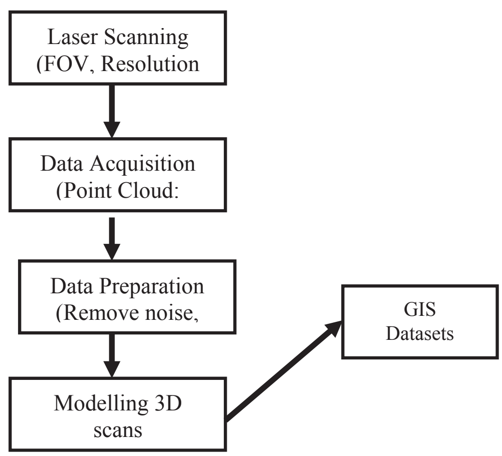


Figure 6: Laser Scanner methodology applied

4. RESOURCES

For the documentation of the monuments and objects of cultural heritage, the 3D laser scanner Leica Scan Station C10 was used (Figure 7) while for downloading and pre-processing of the points clouds the Cyclone software was used. At Cyclone, the necessary cleaning of the clouds was performed and then the registration (when it was necessary) using the scan targets was done. Then the same softaware was used for cleaning, smoothing and optimized the points clouds.

Figure 7: Leica ScanStation C10 (left) and the special targets (right)

5. APPLICATION

5.1 Scan data collection

For scan data collection of the monuments (Figure 8-10), the resolution of the scanner was set to medium resolution. This option gives us an average grid resolution of 1 cm in a distance of 10 m. Since the reconstruction of the façade of the church of Panagia Katholiki and the bell tower of Letybou church were taken form only scan station, no registration was needed to perform.

Figure 8: Data collection in Church of Panagia Katholiki

Figure 9: Data collection from the church of Saint Kirikos and Ioulitis in Letymbou village

Figure 10: Data collection from the church of Saint Theodore in Idalion village

For the 3D reconstruction of the arch in the entrance of the church four scan stations were performed. For the registration of the point clouds the special scan targets were used. For the detail scan collection of the fresco and the icons in Letybou church, the laser accuracy was set in the highest accuracy. The grid resolution was 2 mm in a 10 m distance. Table 1 shows some characteristics of the scan procedure for each monument and object.

Name	Scan stations	Scan Resolution
Church of Panagia Katholiki (façade)	1	1cm@10m
Arch in the entrance of Church of Panagia Katholiki	4	1cm@10m
Bell tower in Saint Kirikos and Ioulitis church	1	1cm@10m
Christ fresco	1	2mm@10m
Saint Kirikos and Ioulitis fresco	1	2mm@10m
Saint Theodore icon	1	2mm@10m

Table 1. Characteristics of the scan stations

5.2 Data processing

After the point clouds were collected (Figure 11), the first step of the processing involves the cleaning of the data. At this stage the noise which was capture during the laser scanning procedure was removed. Cleaning was performed either manually in the Cyclone software for each point cloud or using thresholds of the points clouds (e.g distance of the point from a planar surface).

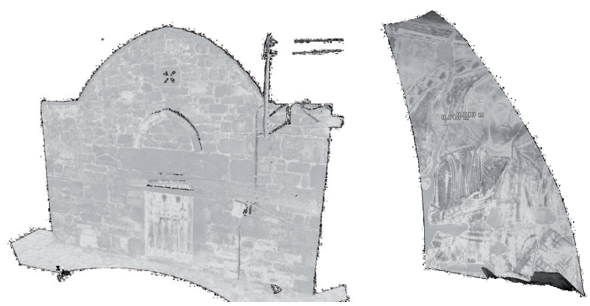


Figure 11: Point cloud of the façade of Church Panagia Katholiki (left) and the fresco of Christ in Letymbou church

The next step of the procedure involves the registration of the point clouds. Registration is the process of integrating a project's scans into a single coordinate system as a registered one. This integration is derived by a system of constraints, which are pairs of equivalent tie-points or overlapping point clouds that exist in two scans. The registration process computes the optimal overall alignment transformations for each component scan so that the constraints are matched as closely as possible. The registration was performed only for the arch of the church in Kouklia village and the Saint Theodore church since only there more than one scan stations were applied.
The mathematical model between two overlapping point clouds can be expressed as a 3D similarity transformation (Manasir and Fraser, 2006):

$$\begin{pmatrix} X_1 \\ Y_1 \\ Z_1 \end{pmatrix} = \lambda \mathbf{R} \begin{pmatrix} X_2 - X^c \\ Y_2 - Y^c \\ Z_2 - Z^c \end{pmatrix} \quad (1)$$

Where:

X1, Y1, Z1: Scan 1 coordinates;
X2, Y2, Z2: Scan 2 coordinates;
R: rotation matrix, which is formed from three axial rotation angles here termed ω, φ and κ;
Xc, Yc, Zc: the translation components between Scan 1 and Scan 2.

Since the laser range data establishes absolute scale, the applicable scale factor λ has unit value, so Eq. 1 represents a rigid body transformation. Once the six transformation parameters (scale is assumed fixed) are computed between the point clouds, the XYZ coordinates of all scan points can be transformed into a common coordinate system (Figure 12).

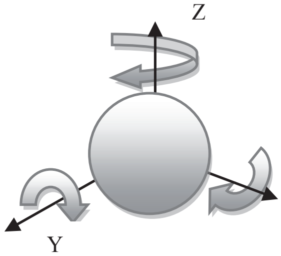
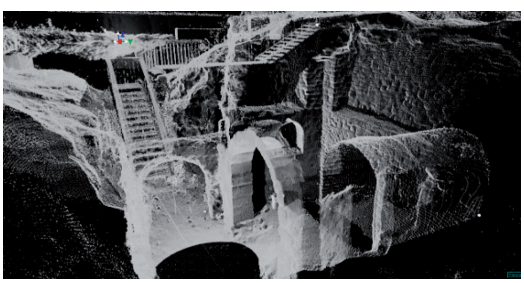


Figure 12: Six degrees of freedom of the registration transformation

The registration procedure was performed in Cyclone software using at first only the scan targets using the ICP (Iterated closed point) algorithm. This is a basic algorithm, in 3D scans, were it automatically aligns a moving mesh M with a fixed one F. The main idea is that we choose a set of (well distributed) points over M and we search on F the corresponding nearest points. These pairs are used to find the most precisely rigid transformation that brings the points of M onto the corresponding points on F. The registration of the point clouds was set as global alignment were the algorithm distributes the alignment error among all the alignments in order to avoid the biased accumulation of error.
After the registration the XYZ coordinates of all scan points can be transformed into a common coordinate system (Figure 13). The registration of the point clouds was achieved with an accuracy of less than 1.5 cm (overall RMS error). However control points measured e.g. by a total station can verify or not this accuracy of the registration.



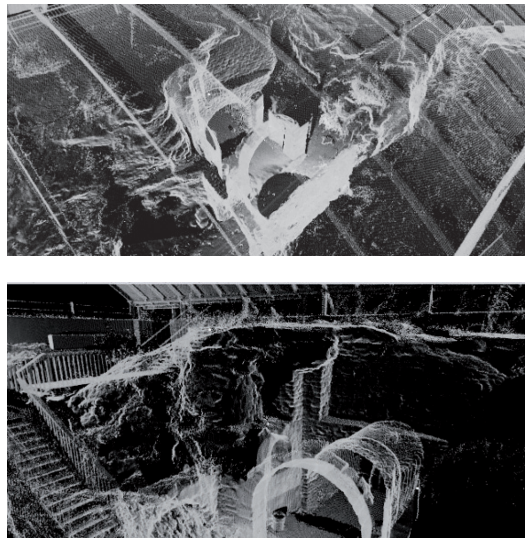


Figure 13: Registration of the point clouds for Saint Theodore in Idalion village. All points clouds are transformed into one coordinate system

5.3 Modelling

After the point clouds were cleaned, the following step was the creation of the surface and the creation of realistic visualizations. The mesh creation was established in the Cyclone software. Complex Meshing to create a mesh consisting of triangles drawn by using trios of adjacent points that are likely to lie in the same plane. The 3D results of this procedure are shown in Figure 14.

Figure 14: 3D modelling of the façade of Church of the Panagia Katholiki at Koukla village (left) and the fresco of Saint Kirikos and Ioulitis (right)

Such kind of data can provide valuable information to researches, architects, local authorities a.o. Cultural heritage sites such as churches are subject not only to natural ageing but also to natural accidents, inappropriate interventions and modifications and vandalism. The use of laser scanner can provide accurate geometric documentation of such buildings through time and monitor them. Such example is the crack presented in the background of fresco of Christ in the church of Saint Kirikos and Ioulitis (Figure 15). Accurate measurements (of few mm) can identify if the crack grew or not. Another application of such technologies is to document any recent anthropogenic (or natural) changes like the example of the bell tower at the church of Saint Kirikos and Ioulitis (Figure 16).

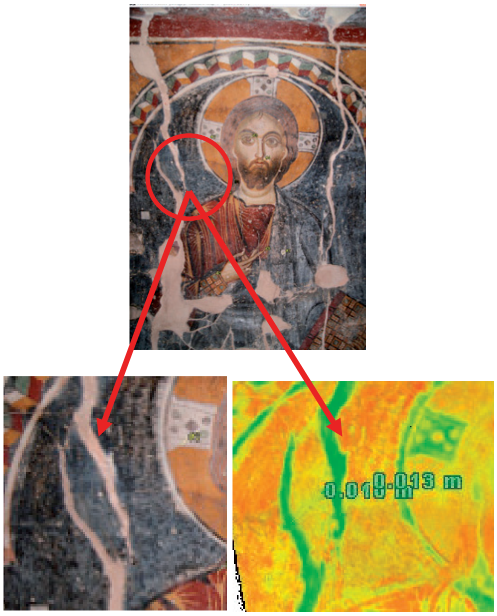


Figure 15: Monitoring the crack of the background of the fresco at Saint Kirikos and Ioulitis through Laser Scanners

Figure 16: Documentation of anthropogenic change of the bell tower at the church of Saint Kirikos and Ioulitis. In circle the recent intervention in the church (photo in the left / 3D laser scan model in the right)

6. GIS DATABASE

GIS, as a digital heritage tool, managed to bring, under one digital tool a vast amount of heterogeneous data. This is a key parameter since the documentation procedure and documentation techniques may have different types of files, both to import and to export. All monuments have been geo-referenced in a common geodetic system (Figure 17). Figure 17 shows a typical example of how a GIS is used to manage the post-processed scanned images as produced by a terrestrial scanner. All the final outputs are stored in a GIS database and all the main and auxiliary data can be available for any engineer or archaeologist for further use. Apollo Leica software is used in this projet to store and manage all the required data.

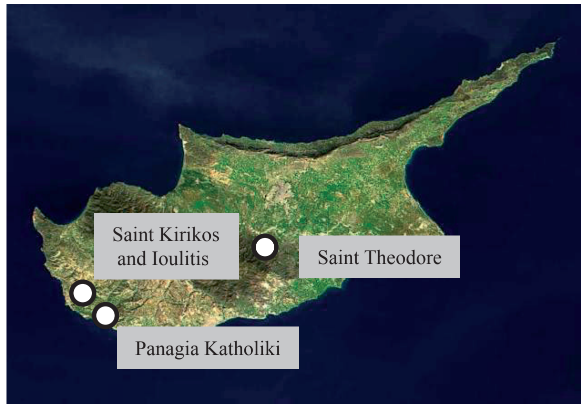


Figure 17: Monuments mentioned in the paper

Moreover some basic characteristics regarding the methods applied for documentation, the date(s) of this documentation carried out a.o. has been formed. Moreover recently taken photographs of the monuments and photographs from the documentation procedure were attached to each monument (Fig. 18). Using a GIS platform any user may easily search the database (quires)

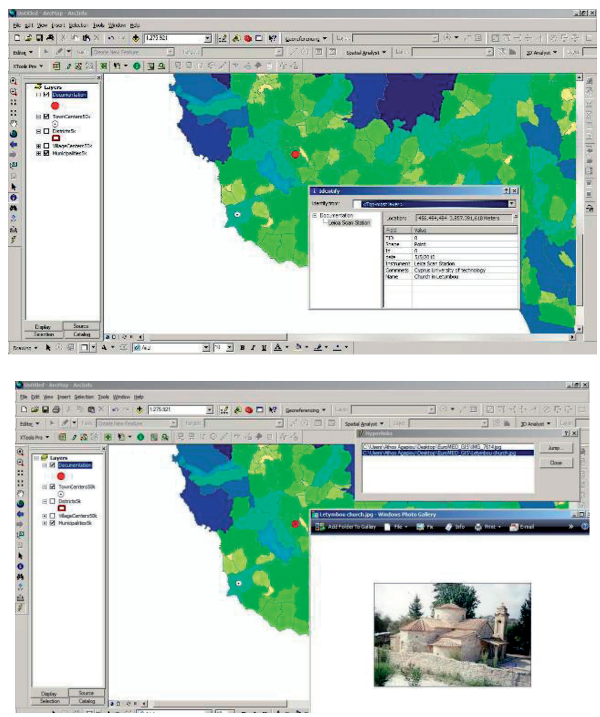


Figure 18: Main characteristics regarding the documentation procedure in a GIS environment (up) and photographs attached (down)

7. CONCLUSIONS

Some simple examples of 3D laser scanner were presented in this paper. The entire process of this application from the data collection was briefly described. The authors will continue to investigate the possibilities of the 3D laser scanner technology for cultural heritage monuments and objects in order to support the digitization process of the cultural heritage of the island.
3D Laser scanning can achieve accuracies of few micrometers, in objects of several meters size, allowing for the detection of very small features in the artwork surface and a very detailed documentation of the object as shown in this paper.
The use of GIS has been used as a tool in order to monitor the documentation carried out in different parts of Cyprus and in different times.
However a more detail database should be performed in order to be able to entry all the necessary information regarding monitoring documentations carried out in Cyprus. Moreover the creation of a web-based GIS environment friendly to the end-users (e.g. Department of Antiquities in Cyprus) may maximize the interest from the local authorities to used such technological tools.

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PROJECT "REVITALIZATION AND DIGITIZATION OF THE SEVENTEENTH-CENTURY PALACE COMPLEX AND GARDEN IN WILANOW – PHASE III" TASK "3D DIGITALIZATION OF SELECTED EXHIBITS COLLECTION"

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KEY WORDS: 3D digitization, structured light, Greek vase, biscuit, sandstone vase, sarcophagus of Stanislaw Kostka Potocki, Chinese Cabinet, Museum Palace at Wilanow

ABSTRACT:

The task "3D digitization of a collection of selected exhibits" is part of the project entitled "Revitalization and digitization of seventeenth century palace complex and garden in Wilanow – phase III". Museum Palace at Wilanow is one of the most famous cultural heritage centers in Poland. The aim of this task was to obtain faithful documentation of cultural heritage objects useful for conservators and art historians. Metrological parameters for all kinds of objects were proposed, discussed and approved by both the conservators, who compose the collection and engineers, who prepare the instrumentation. In order to be able to meet the requirements, researches linked with the measurement system, data processing and visualisation had to be carried out. During 6 months three configurations of the measurement system and its positioning devices were prepared and more than 20TB of data has been collected and pre-processed.

1. INTRODUCTION

Art historians and conservators usually oppose to the idea of creating virtual models of cultural heritage objects for purposes other than rough visualization, done mainly as an approximate demonstration of what is to be seen in reality. The main doubts concern the accuracy and fidelity of the models, which have tended to lack the subtleties and details significant for the specialists.
This project was established to deal with those problems and create useful, faithful documentation of a collection of cultural heritage objects of various types, dimensions and degree of complexity. The project was started in October 2009, will be finished by September 2011 and is divided into 8 stages, each about a quarter long.

1.1 Museum Palace at Wilanow

The Museum Palace at Wilanow is one of the most famous places connected with art and culture in Poland. This wonderful baroque royal residence belongs to those few places of interest in Warsaw, which remained in its intact form over the period of the Second World War. There are various kinds of permanent exhibitions inside the palace, divided into thematic zones, and in the Orangery temporary exhibitions and educational events are arranged. The Palace Park is open for visitors.

1.2 Task

The objectives behind the current task include creation of documentation useful for specialists performing various operations on the objects, such as research and restoration.
The idea is to create a model of the object covering its shape, texture and colour by collecting a dense enough cloud of points able to show the complete structure of the object's surface. The prepared documentation may be used to control the object's condition in time – comparison of models from various periods of time gives the opportunity to examine the nature of changes taking place on the surface of the object. The models can be used as a utile tool for understanding better the aging processes and factors which influent it.
The process of establishing the documentation is connected with specific stages of processing of the measurement data, such as filtration, merging, simplification and triangulation. The unique character of the objects to be measured together with requirements put on the final models demanded that research in all of these fields was carried out.

2. GOALS AND METHODS

Objects selected by the specialists vary in size, colour, surface condition and complexity. In the first quarter of the project the Chinese Cabinet was measured, which is a chamber 5 meters high and has an area of 16 square meters, which gives about 100 square meters of surface to measure (only the floor was omitted). The walls of the cabinet are covered with wooden relief painted with shiny lacquer, which is problematic for optical measurement systems because of light reflections, which can cause noise to appear in the measurement data.
Another part of the collection was a set of Greek vases. From the measurement system's designer point of view, the biggest advantage of such objects is their axial symmetry, which allows to use a rotary stage to automate large part of work. The surface of the vases is shiny and the painting is very dark – most of the surface is close to black and the other colours are different shades of brown. For the measurement system dark colour means low modulation of captured images and, as mentioned before, measurements of reflective surfaces are very prone to noise. All in all, the Greek vases can be characterized as having simple shape though difficult to measure colour characteristics.

Objects of a completely opposite character are biscuits – their surface is bright and scattering, but on the other hand very complicated and full of minor details.
In the next stages of the task measurements of the sarcophagus of Stanislaw Kostka Potocki and sandstone vases are planned. For those objects, the biggest challenge will be their overall dimensions and the necessity to perform the measurements outdoors.
Table 1 containing metrological parameters accepted for selected objects is shown below.

Object(s)	Spatial resolution		Measurement uncertainty
	mm	points/mm^2	mm
Chinese Cabinet	0.1	100	0.02
Greek vases	0.025	1600	0.01
Biscuits	0.01	10000	0.005
Sandstone vases	0.02	1600	0.01
Sarcophagus	0.1	100	0.02

Table 1. Metrological parameters for objects

2.1 Measurement method

The measurement systems used in the project are based on structured light illumination (Sitnik, 2002a). Each system consists of a projector, which displays raster images with a predefined pattern on the surface of the measured object, and a detector, which captures the images of the pattern deformed by the surface of the object. In this particular case the sequence of images consists of a set of sine images shifted in phase and a series of images forming Gray code. Then, using the acquired images, real coordinates of the surface are calculated for every pixel of the detector.
The sequence of phase shifted sine patterns is connected with the Temporal Phase Shifting technique (Patorski, 1993), which allows to calculate a phase map from a set fringe patterns knowing the actual, artificially introduced phase shift between them. The next step is to unwrap the phase map, i.e. eliminate phase discontinuities formed as a side effect of the phase calculation algorithm. Thanks to the acquired images containing Gray code, each period of the projected sine patterns can be ascribed a unique number corresponding to multiple of 2π, which should be added to the wrapped phase to obtain the final phase map.
Coordinates of the surface can by calculated only for its part located within the measurement volume. This volume is a part of space defined during the calibration process (Sitnik, 2005a), when a known object, the master, is placed in a number of predefined positions according to a schema. Analysis of the measurements of the master makes it possible to find the relation between the phase map calculated on the basis of the measurement images and the master's geometry. The most important issue connected with the stability of the system is to keep the relative position between the detector and the projector constant.

2.2 System positioning devices

The dimensions of the Chinese Cabinet are large in relation to the size of the system's measurement volume, which is 0.5 x 0.4 x 0.2 m^3. To create a model of the whole chamber, it was necessary to reposition the system many times. To avoid the problems with changing the position of the measurement system and finding the correspondence between different measurements, a telescopic positioning device was proposed. This device allows to adjust the vertical and horizontal position of the system in a controlled manner and without effort. Figure 1 presents the system mounted on the positioning device used during scanning of the Chinese Cabinet.

Figure 1: Chinese Cabinet – the measurement system

Objects such as Greek vases are relatively easy to measure as the measurement process can be automated. Vases were placed on a rotary stage, alas the height at which the system was positioned had to be adjusted each turn of the stage due to small size of the measurement volume.
However, the most difficult problem faced was setting the position of the measurement system where it wouldn't record reflections from the surface of the vase. For this reason a robotic arm was used, which makes the positioning process rigid and stable. Only the areas close to the handles were more complicated and required manual positioning of the system (Figure 2).

Figure 2: Greek vase – the measurement system

3. THE RESEARCH

3.1 Measurement system construction

The design of each of the measurement systems used requires taking into consideration the character of the objects and the metrological parameters to attain. The systems consist of a detector and a projector, where the relative position of those and the focal length of the projector and detector lenses decide about the system working distance and the size of the measurement volume (Figure 3).

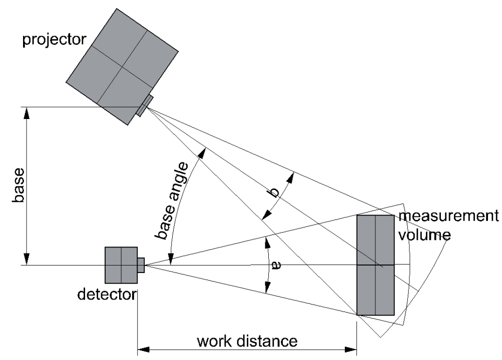


Figure 3: Measurement system setup

The base angle determines system’s sensitivity, which is strictly connected with measurement uncertainty (Kujawińska, 2003). If this angle is too small, the required measurement uncertainty is impossible to obtain. On the other hand, too large base angle causes the common part of space simultaneously illuminated by the projector and observed by the detector to be relatively small. In consequence, to determine the optimal system configuration a two step research has been done – first the theoretical values of the system configuration parameters were calculated, and then the final position of the elements was adjusted experimentally during tests.
The character of the Chinese Cabinet allowed to assemble a multidirectional measurement system, as significant percentage of the surface of the chamber was planar. For this task, four single-directional measurement systems were placed on a common frame (Figure 4). The measurement systems were positioned with respect to each other so that the adjacent measurement volumes overlapped, forming together one complex measurement volume, which was defined during a common calibration process.

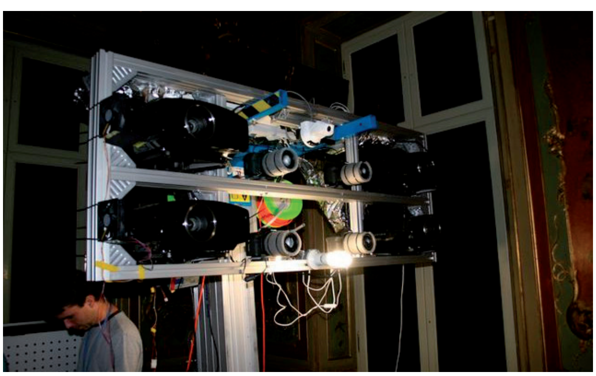


Figure 4: Multidirectional measurement system.This solution speeded up the process of collecting the data thanks to the reduction of indispensible system position changes

Until this moment configuration requirements for the measurements of biscuits, which will be performed in the next stage, were analysed as well. In a consequence of required measurement resolution, which was defined as 0.01mm, custom made lenses for the projector had to be prepared, as market solutions were insufficient in this particular case.

3.2 Measurement system calibration

Each measurement system was calibrated (Sitnik, 2005a) using a planar master with an array of circular markers printed on its surface (Figure 5). Analysis of the images of the master captured by the detector allows to find dependencies between the master’s geometry and the phase map obtained using the Temporal Phase Shifting technique connected with unwrapping using Gray code. The process is divided into two parts – geometric and phase calibration, where the master has to be measured in, respectively, 6 and 4 predefined positions (Figure 5). The result is a calibration matrix which stores the geometry-to-phase relation map within the whole measurement volume. This kind of calibration is referred to as experimental, because no *a priori* information about the elements of the measurement system nor their configuration is needed.

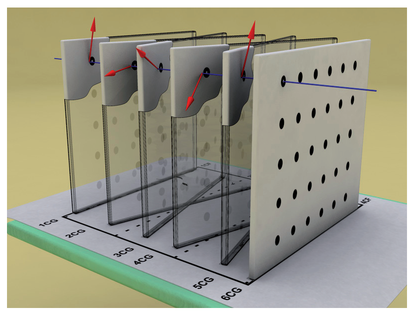


Figure 5: Sequence of the calibration master positions

In this task a common calibration process was developed as well, which gives the possibility to merge measurement volumes for systems placed next to each other. For this reason, a special calibration master was prepared (Figure 6).

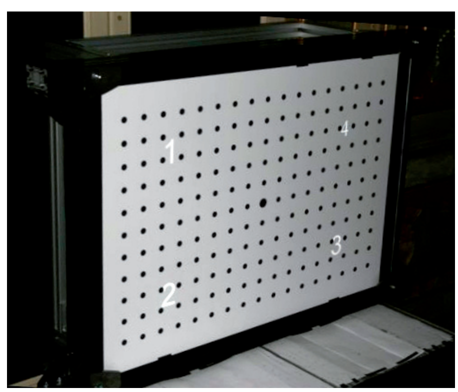


Figure 6: Calibration master for the common calibration

One of the markers on the master’s surface is distinguished. This extra information is used to calculate the relation between adjacent measurement volumes and makes it possible to perform measurements using four single-directional systems that are treated like one complex system.

3.3 Measurement uncertainty verification

All proposed system configurations were tested for metrological parameters. Resultant clouds of points were analysed for spatial resolution and measurement uncertainty. During measurements the metrological parameters were also verified to avoid collecting data with insufficient accuracy or resolution.

3.4 Data filtration

As was mentioned earlier, algorithms dealing with filtration of incorrectly measured points are necessary, be that measurement errors caused by the measurement hardware, data calculation path or simply by the properties of the measured object. First two algorithms (Sitnik, 2005b) are proposed for the filtration of noise – both remove points placed too far from a locally best fit shape, with the shapes chosen as plane and sphere (Figure 7).

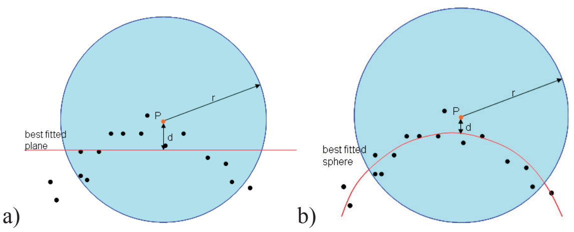


Figure 7: Noise point (coloured in red) for: (a) best fit plane, (b) best fit sphere

Both algorithms work interchangeably and the result depends on the results of local surface shape curvature analysis. The result of those algorithms – selected noise points – is shown in Figure 8.

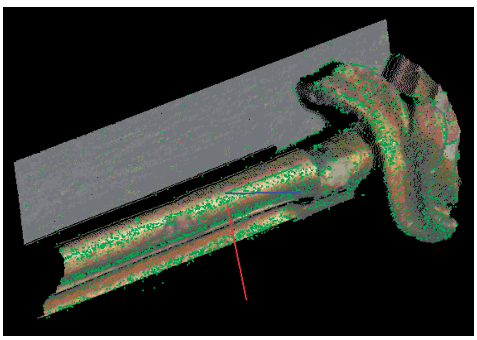


Figure 8: Noise points selected by the algorithm – coloured in green – detail from the Chinese Cabinet

The next algorithm uses the Hausdorff criterion and removes small groups of points located too far from the rest of the cloud of points. Algorithms removing packets of erroneous points created due to overexposure, caused by shiny surface of the objects are also implemented – overexposed points are selected on the basis of colour. Another group of filtration algorithms is connected with the analysis of points located at the edges of the cloud. The algorithms presented above were customized especially for specific kinds of objects: the Chinese Cabinet and Greek vases.

3.5 Data simplification

A single cloud of points from the measurement system used in this project contains approximately 10 million points. In real time 3D environments surfaces are represented as meshes composed of triangles. Triangulation is a computationally expensive operation, strongly dependent on the amount of input data, i.e. the number of points in a cloud.

The goal was to develop a flexible simplification algorithm (Sitnik, 2002b) or a set of algorithms for different objects, that will support triangulation of data of reduced size, but with preserved details.

So far the Chinese Cabinet and Greek vases have been measured – both types of objects have irregular distribution of geometric details and thus simplification can be done in regard to local geometrical complexity.

The complexity of 3D geometry was evaluated based on the fitting error of a locally best fit plane. For a flat region the interpolating plane is well fit and the error is small. High-detailed regions produce high plane fitting error.

As proposed, the local simplification radius is a function of local geometrical complexity. It is evaluated iteratively as a greatest radius, for which the plane fitting error does not exceed a given value. Flat regions are simplified to a much greater extent than highly-detailed regions, such as oriental wall adornments in the Chinese Cabinet (Figure 9) or paint irregularities on the cabinet's ceiling.

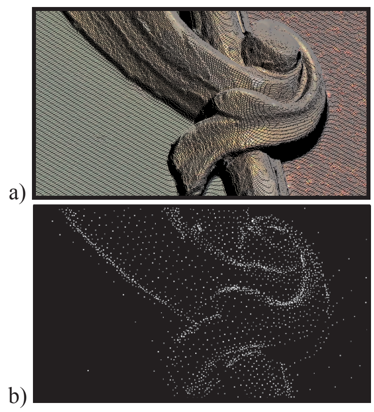


Figure 9: Detail on the Chinese Cabinet wall (a) after adaptive simplification (b)

Tests of the proposed algorithms on the Chinese Cabinet and Greek vases data have shown good results.

3.6 Data visualization

The aim was to design and implement a visualization method for large sets of measurement data (up to 10^{10} points) in the form of clouds of points. The necessity for such is imposed by the volume and resolution of data obtained in the latest measurements of objects such as the Chinese Cabinet, where the measured area exceeds $100 m^2$. No existing visualization software can display such amounts of data, not without either dividing the final model into many small parts, which prevents the viewers from seeing the entirety of the object and limits the use of such a model to a very narrow field, or simplifying it, thus losing the remarkable resolution attained during the measurement, very much valued by the conservators, who can start to treat the virtual model as an actual, faithful copy of the real object with all its details and subtleties.

The problem can be split into two main sub-problems: viewport culling and change of resolution. The point character of data has both advantages and disadvantages in this aspect – it is possible to partition the data in space in a very straightforward manner, without having to worry about objects on the boundaries of partitioned space, but on the other hand the amount of data makes it difficult to index it. Because of these properties, the classic octree structure was selected for spatial partitioning of data, since most of its defects is connected with finite size of objects in the system. Octree is a tree data structure, where each node has either maximum or exactly eight children (based on implementation). This concept can be easily spanned to three dimensional space, where all of the data can be bounded by a cube of some size. The cube is then divided into eight parts using three divisions, one in X, Y and Z direction, and the process is continued recursively for the new cubes. The cubes of smallest size are referred to as voxels – the equivalent of pixels in 3D (Akenine-Moller, 2002).

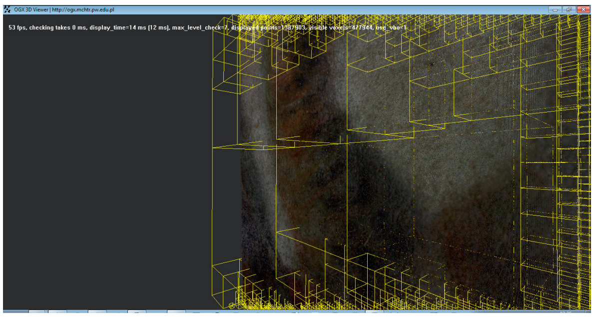


Figure 10: Part of the ceiling from the Chinese Cabinet and nodes of the octree at different levels

This structure can be later used to select very precisely and effectively data in a defined volume. This volume can be seen as the viewport – part of the virtual space that is visible to the user in each moment. Clipping the viewport is then performed using six planes imitating the field of view of a camera, based on a recursive algorithm, which starts from the top part of the octree and checks the positions of the cubes with respect to the planes using the point-to-plane signed distance formula. If any of the planes intersects a cube, its children are then checked in the same way. Only data which passes this test is displayed, along with data on the borders of the screen to prevent any visual artifacts (Figure 10).
Once only data visible to the user is selected, the next problem becomes how to choose the proper resolution, so that all the relevant details are shown, yet no redundant information is given. The solution is to select the resolution based on the position of the object with respect to the user. Moreover, screen resolution used to display the model has to be taken into account, since no more than one point per pixel can be resolved, but to benefit from the excessive data present in the model the best impression would be obtained if the point character of the data could be hidden, i.e. if no two points can actually be resolved by the viewer. The application can then display the data in a close to the minimal, yet slightly smaller resolution for a given position.
Next part of the work will be focused on optimization of the implemented algorithms to obtain higher display efficiency (e.g. parallel implementation of spatial data selection) and experimenting with different methods of display, as even though the data is accurately and effectively selected, most of the graphics hardware is optimized for work with triangle meshes, not point data, which affects the overall performance of the visualization (Woo, 1999). Enhanced lighting will be implemented as well.

3.7 Data comparison

The goal is to create algorithms for evaluation of the changes that had taken place on the surface of the objects. A visualization of losses and surpluses on objects with statistical information based on the comparison allows conservators to perform an objective estimation of the change of condition of the object in time more easily.
The results obtained are two algorithms analyzing digital data describing changes of the object in two ways. The first algorithm is called "Point-to-Point" and the result of the comparison is the distance between a point from the cloud under investigation and its closest point from the base cloud. The second algorithm is called "Point-to-Plane" and the difference with respect to the first one is that instead of the closest point in the base cloud, a plane is determined from points belonging to the base cloud and found in the neighborhood of the analyzed point.
The analysis of the results is carried out with the use of visualization and basic statistical parameters (Figure 11). The most important parameters include: root mean square (RMS), absolute deviation value, average deviation value.

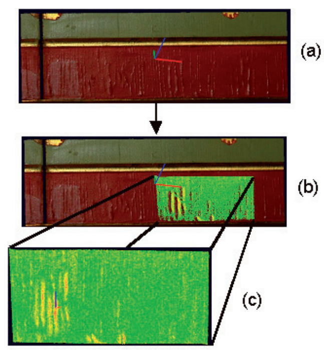
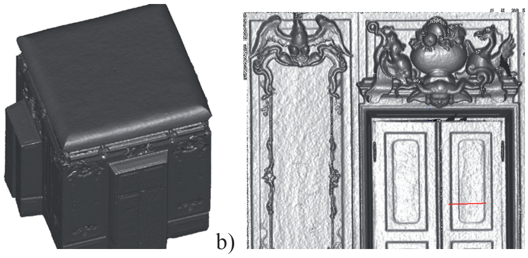


Figure 11: Result of comparison of two measurements: (a) base cloud of points, (b) analyzed cloud of points, (c) result

3.8 Triangulation

The aim was to cover the issues of converting data in the form of clouds of points into sets of triangles (triangle meshes). There are two main reasons this conversion is needed. Firstly, this kind of object surface representation is widely used in computer graphics for visualization and editing and thus display hardware is optimized for processing meshes. Second important issue which makes triangulation important is the growing popularity of 3D printing, for which input data is also in the form of a triangle mesh.
Measurements done within the scope of the discussed project are very dense (up to 10^3 points per mm^2). Direct triangulation (Sitnik, 2008) of those datasets would be unusable (commercial software packages are not prepared to deal with models which utilize few gigabytes of memory) and clouds of points for triangulation must be previously simplified (to obtain possibly small point count while retaining good surface representation).



a) b)

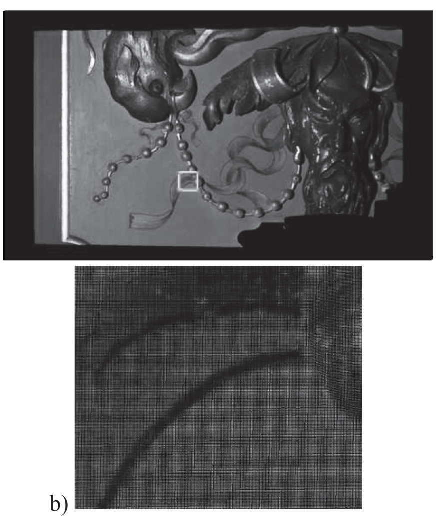
Figure 12: Exemplary triangle meshes of simplified data from the Chinese Cabinet: (a) the Cabinet itself, (b) part of the wall seen from inside

As a first task in the project, the analysis of data obtained in the Chinese Cabinet was made. High percentage of the measured object's surface is closely comparable to a plane and therefore the triangulation algorithm developed for this data relied on the division of model's cloud of points into quasi-planar regions, for each of which two-dimensional Delaunay triangulation (Cignoni, 1998) was applied. This algorithm deals efficiently and accurately with both homogenously and adaptively simplified clouds of points.

In the next part of the project, the developed algorithm was supplemented with a procedure for connecting sub-meshes obtained with two-dimensional Delaunay triangulation (Figure 12).

4. EXEMPLARY MEASUREMENTS

The idea for the measurement of the Chinese Cabinet was to carry out measurements with a resolution not less than 0.1mm. About 3500 measurements were made using a multidirectional measurement system, which gives a total of 34 billion points. Example of a single measurement result is shown below (Figure 13).



a)

b)

Figure 13: Exemplary cloud of points: (a) single cloud of points – 10 million measurement points, (b) magnification of a selected area

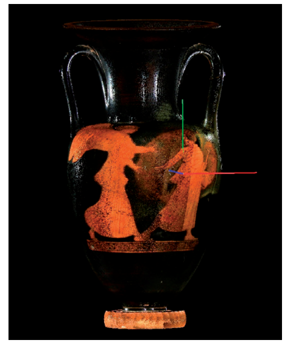


Figure 14: Exemplary cloud of points of a Greek vase — 1.8 billion measurement points

In this project, the measurement of 18 Greek vases was planned. Currently the last two vases are being measured. For each of the vases about 2 billion points were collected, obtained in about 500 measurements (Figure 14).

5. CONCLUSIONS

The task is carried out according to schedule. Now, after the Chinese Cabinet measurements and 16 Greek vases, we begin preparations for the measurements of biscuits. Under development is the construction of a measurement system that would meet the metrological requirements for these objects.

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PHOTOGRAMMETRIC SUPPORT ON AN UNDERWATER ARCHAEOLOGICAL EXCAVATION SITE: THE MAZOTOS SHIPWRECK CASE

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KEY WORDS: Underwater, archaeology, documentation, photogrammetry, 3D reconstruction, object modelling

ABSTRACT:

This article highlights some aspects of utilizing surveying, photogrammetry and machine vision techniques for the purpose of underwater archaeological site recording. Considering typical methods, the approaches investigated here contribute in their appropriateness for rapid data production. Different approaches according to deliverables, requirements and specifications are provided at each stage. The initial methodologies applied here need to combine high versatility, dictated by the demanding underwater environment, with acceptable measurement quality, indicated by the need for metric outcomes. Main tasks of the Mazotos shipwreck project include rapid production of photomosaics for communication and overview use, artefact 3D modelling, underwater camera calibration, photo-triangulation with bundle adjustment as well as point cloud extraction using dense photography and video for site modelling. The diversity of tasks imposes the need to follow different approaches that combine different, often open-source, non-dedicated, tools. The initial results presented here highlight open issues that comprise considerations for the next development stages of the project.

1. INTRODUCTION

Mapping of underwater environments has been a task with significant work recorded in the literature (Canciani et al., 2002; Chapman et. al., 2010; Drap et al., 2007; Ludvigsen et al., 2006; Pizarro et al., 2009). Yet, archaeological site mapping using photogrammetry, still poses many difficulties, specifically when application frameworks need to be implemented in the special case of underwater excavations, where on site processing and fast data production are of high demand. In particular, the combination of 3D site mapping with the archaeological excavation documentation, which poses by default a dynamically changing environment, can be still considered to be a very challenging task for photogrammetry. To maintain metric quality of the derived products together with speed and versatility of the results during artefact removal, the proposed approaches need to vary with regards to equipment, methodologies and analysis tools. Thus the outcomes presented here are expected to be evolved together with the implemented and proposed approaches.

1.1 Mazotos shipwreck: The study area

The underwater shipwreck of Mazotos has been investigated since 2007 by a team of the University of Cyprus, under the direction of archaeologist Dr. Stella Demesticha, in collaboration with the Department of Antiquities of Cyprus and the THETIS foundation. However, the first systematic excavation was conducted the period May-June 2010, during which a detailed mapping and documentation of the findings position on a daily basis were set as main tasks of the project. These tasks set a main difference with regards to underwater archaeological site mapping, that for example allows gathering all necessary data at a first phase and subsequently post processing these at a later phase. Thus, time regarding data collection and processing was expected to comprise a significant parameter in the project tasks. The Cyprus University of Technology (CUT), Department of Civil Engineering and Geomatics undertook the underwater mapping support of Mazotos wreck. The wreck is located in southern Cyprus, situated approximately 2 miles from the coast and in 45 meters (m) depth. The ship was sunk under unknown circumstances, carrying large amphorae used to transport wine from the island of Chios (Greece) to Cyprus. The size of the exposed cargo was approximately 17 m in length and 8 m in width. Fortunately for the site engineers, the ship was laid in a sandy flat bed, nearly intact. Therefore, it can be regarded to be approximately horizontal, or more precisely, slightly inclined as the cargo is almost in position.

The archaeological requirements for the Mazotos project, as defined by the archaeologists are summarized in the following tasks:

1. Mapping of the shipwreck's condition as it was discovered and prior to the excavation.
2. Daily monitoring of the trench's process.
3. Daily artefact monitoring and mapping of the artefacts' 3D location to enable 3D reconstruction of the wreck at the stage of full ship excavation.
4. 3D measurement and modelling of the site's pertinent artefacts such as the amphorae.

To place in context the listed products required for archaeological analysis, further considerations regard primarily speed of data acquisition as well as automation of the processing chain (e.g. system calibration, measurement and modelling). Artefacts can only be removed after their location has been recorded, which means that the developed methodologies need to be fast and accurate, distinguishing these

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from typical mapping approaches. In addition, non-dedicated software outcome is desirable to facilitate 'easy' analysis and interpretation from all members of the team including the non-photogrammetrists. Data acquisition, processing and outcome become demanding particularly when considering the difficult conditions that prevail underwater. Yet there exists one cost, that for photogrammetric processing and analysis is essential, and this is the expected reduced accuracy of the results. Underwater photogrammetry has been covered in the literature covering both the topic of camera calibration (Kotowski, 1988; Lavest, 2000; Maas 1995) as well as modelling (Drap et al., 2007). The main contributions of this paper are:

- Application of machine vision techniques in conjunction with photogrammetry for the purpose of underwater mapping.
- Implementation of open source tools as much as it is possible for under and over water modelling and analysis.
- Application of the aforementioned techniques daily and repeatedly in an underwater excavation site instead of post processing data for underwater mapping alone.

Some overall results from the proposed techniques are presented as initial samples of the expected outcomes. It should be noted that metadata of 3D datasets, which are recorded as part of the archaeological excavation log and e-preservation, which is of utmost importance, were out of the scope of this year's research framework. In particular this years research from CUT's scope, was concerned with the 3D capture methodology.

1.2 Problems and limitations

By definition photogrammetry is connected with the term 'Art' in the context that: *"Photogrammetry is the art, science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant energy and other phenomena"* (Mc Glone, 2004). The word "Art" is being used to highlight the need for sharp, net photography. Whilst this term is gradually disappearing in most recent definitions, it can be regarded that it connects photogrammetry with the concept of visibility, which is rapidly deteriorated in the depth of the Mazotos shipwreck monitoring. As an example, depending on prevailing conditions, it is not unusual for objects located at a range of 10 m to be merged with the blue background. The red part of the visible spectrum is absorbed almost completely at any distance. Divers can work for a net time of 18 minutes in that depth, before they start the decompression sequence and resurface. In addition, divers may suffer from depth narcosis which makes even simple tasks such as tape measurement readings (typical tasks in ~20 m depths) difficult to be executed. Here due to the 45 m depth, available time for data collection and human physical condition at that depth, photogrammetry is selected for the main recording tasks. Besides recording, photogrammetry's ability to perform image matching for 3D object modelling is considered to be irretraceable. Of course image-based modelling is affected by the key issues of precise camera calibration, object space control and occlusion. For example the camera needs to be calibrated within the water medium accounting for the effect of refraction (the refractive index of water can be affected by depth, temperature and water salinity). In addition, whilst it is highly difficult to establish control, it is expected that control points established underwater should be measured with an 1/3 accuracy over the whole block. Finally, in the object modelling aspect, occlusion comprises an open issue. Hidden objects can not be fully recovered; hence undercuts or lower level amphorae can not be mapped until the upper layer is removed as an example.

1.3 Underwater photogrammetry

Considering conventional photogrammetric mapping, main characteristics of underwater photogrammetry comprise the following:

- Data acquisition: Limited on-site accessibility for data collection together with the absence for operational control over the data collection (usually implemented by a non-surveyor diver).
- Illumination: Site illumination is affected by the absorption of red wavelength at a very close range (~1.5 m) even with strong artificial light sources.
- Camera calibration: Two (water and air) media data collection that affect camera calibration and accurate 3D object measurement.
- Object control: Establishment and provision of 3D control with adequate accuracy is prohibited with surveying methods such as tape measurement and 3D triletaration.
- Object measurement: Diffusion of light poses object recognition difficult at imaging ranges of up to ~10 m and sets an imaging range of 6 m for the tie point measurement.

It is indicated that in close range imaging, diffusion can be tackled with utilization of wide-angled cameras. Fortunately this ensures good geometry (wide base to distance ratio) but it can enhance the internal camera distortions as a trade off. The data acquisition experience proved that the 'correlation' between the diffusion of light (that forces us to close range photograph the wreck) with the effect of parallax (that occurs in such close range, wide-baseline situations) can not be avoided.

1.4 Previous work and existing data

The reader can find previous work regarding studies of the Mazotos shipwreck in Demesticha (2010). Here we outline a brief review. At the outset of the discovery of the wreck, the main objectives were the documentation of its state as well as the shape recording and 3D positional mapping of its amphorae. As mentioned in Demesticha (2010), drawing of the different types of the amphorae was done based on underwater measurements collected with conventional instruments such as plastic tapes, callipers, quadrant compasses and metal rulers. The final 3D product of these measurements was a revolved design.

Within this work in order to treat 3D site mapping, we selected to utilize the available Photomodeler scanner software (Canciani et al., 2002; Green et al., 2002; Drap et al., 2007) and the available DSLR Canon A620 camera. To give a sample of the data processing chain within Photomodeler, one dataset was processed with a selected number of 119 images (total number of images= 350) accumulated in three dives during two different field-seasons. The photos were collected with an orientation ranging between 45-90 degrees with respect to the sea bottom (nadir-looking) covering a total area of 17.5 x 8 m. In order to identify the amphorae, a 10 cm diameter plastic disc with a coloured cross-wire black and yellow pattern was wrapped in the rims forming a small plane utilized to manually position the amphorae in 3D space. For scale recovery, a 2 m bar and several sub bottom buoys for vertical direction were used to introduce some survey constraints to the otherwise free network. This dataset was processed with a bundle adjustment with self-calibration for 3D positioning of the 140 amphorae. To report an example of the achieved precisions, maximum standard deviations of σX= 0.034 m, σY= 0.064 m, σZ= 0.052 m have been observed among the 771 measured 3D points. Processing revealed that significant image point residuals had to be detected and removed from the process. Although bundle adjustment processing with real world datasets and the available software can be regarded as trivial; main shortcomings were related to target measurements originating from (a) the dependency of the 3D orientation of a typical 1 m in height amphora to the determination of a 10 cm diameter target plane; (e.g. any uncertainty in this small plane is propagated to the the amphora's orientation) and (b) the targets non strict rigidity and planarity (e.g. any uncertainty in point measurements affects photogrammetric triangulation accuracy). To include a control network, control was established using 1m in height plastic tubes fitted to cement blocks and subsequently measured with tape trilateration surveys and basic photogrammetry. However the low precision of the results excluded inclusion of these measurements in further implementations.

Figure 1: Photomosaic of the whole wreck (left) and plastic disks on amphorae rims detail (right) (courtesy of B. Hartzler, © University of Cyprus, ARU)

2. PHOTOMOSAICS

Extensive discussions with archaeologists and personal communication with B. Hartzler, concluded that the usefulness of the mosaics as part of the excavation process is largely related to communication and planning. The ability to explain and show the team where to go and what to do can be considered as immense in underwater excavations. In addition, it serves the purpose of site documentation particularly as the trench gets deeper and new findings are revealed. Furthermore, photomosaics comprise useful products for deformation analysis, monitoring changes that may occur amongst different excavation periods. As a result, considering the aspects of simplicity, speed and interpretation, a mosaic can be considered as a valuable product. Whilst of poor geometric quality, its radiometric quality and invisible seam lines are surprisingly good when considering the object's 1 m relief in relation to the 2.5 m object to camera distance and the utilized number of photos. However, the mosaic presents significantly low precision with discrepancies reaching ~0.9 m in comparison to control (as calculated with Photomodeler software). Several mosaics were produced within the excavation period of 2010. Photography was acquired with the available DSLR Canon A620 with fixed focus and without flash settings. Vertical photography was acquired from a 6 m distance aiming at a sidelap and overlap of 70%. It is indicated that underwater conditions often prevent even experienced divers from regular spaced photography while operating the camera equipment. As a result, the imaging range varied between 4.5 and 5.8 m within the same photo session. Image quality was considered to be poor, as a result of the diffusion effect (demand for close range photography) and coverage (demand for far-range photography). The approach followed here employs open-source or free software and it is fast enough to produce for example a mosaic composed of 50 photos, within one hour, with a minimum or no manual effort at all; setting the main product necessary to be generated on a daily basis for archeological analysis. 3D site modelling and findings positioning, although necessary, were of less significance at the present excavation process; hence these comprise primary products for our further development tasks. Figure 2 provides an example of a generated photomosaic during the period May-June 2010, repeatedly produced after every photographic dive.

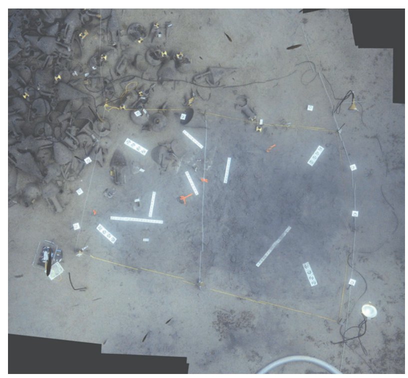

Figure 2: Photomosaic of the trench (courtesy of B. Hartzler, © University of Cyprus, ARU)

It is noted that the object's relief suggests that orthophotomosaic production would require significant processing time, post processing and editing. For instance orthophoto production of a similar block would need at least 10 days on a standard softplotter. An orthophotomosaic is currently under production for comparison purposes.

3. BLOCK ADJUSTMENT

3.1 Camera calibration

Lavest et al., (2000) treat the problem of underwater camera calibration considering both air and water media. Whilst simulation can provide a good answer, the effect of refraction (the refraction index of water depends on a number of parameters such as depth, temperature and salinity) can cause unstable modelling effects in the context of the classical photogrammetric camera calibration. In our case, the camera was enclosed in a waterproof Ikelite housing with the interference of additional optics in optical line. As a result, we treated the camera-housing system as a whole. For our aim we adopted the bundle adjustment processing within the Photomodeler scanner software using the provided 0.9x0.9 m planar calibration test-field. To evaluate camera calibration, prior to the procedure we followed here, two camera calibrations were tested utilizing the camera housing and excluding the housing from the system. Data processing is expected to show whether and how housing and water interface affect determination of camera calibration. High foreground to background underwater imagery was generated with image pre-processing, particularly essential in 45 m depth where the diffusion effect is significant. The images were collected from a range of 2.5 to 3.0 m with regards to the demands for strong convergent network geometry as well as test-field frame coverage. In addition, considering that photography of the wreck would incorporate vertical (designed from an acquisition range of 5 to 6 m) and oblique imagery, an average focus distance of 3.5 m, assuming a circle of uncertainty of 2 μm, and an aperture F#1/8 were selected. Thus, objects that varied in imaging range between 2.25 to 7.82 m were marginally in sharp focus. The calibration results were utilized to initiate the block adjustment and the additional 3D measurements implemented within Photomodeler and ZI's Imagestation softwares.

3.2 Network design and planning

Personal communication with the head architect of the project, F. Vlachaki led to the consideration that one of the main tasks that the previous excavation period revealed, was the establishment of a control network. The surveying network was created by the establishment of eight 1 m tall plastic tubes fitted to cement blocks as control, measured with tape trilateration and basic photogrammetric processing. The tape measurements were processed with the Site Recorder software but its output was considered of low precision and therefore it was not utilized for any further calculations. The incorrect results were attributed to potential divers' narcosis, which may lead to fussiness (e.g. erroneous holding of the tape's zero point and recording measurements together with an inability to ensure the tape's straightness because of local currents and amphorae protrusions). However, control and check point measurement are of high importance for photogrammetric methods. The rule of thumb requires that control is of approximate accuracy of 1/2 to 1/3 over the photogrammetric block considering photo scale and the utilized camera system. In our case accuracy requirements were defined by the team of architects and archaeologists. Archeologist Dr. S. Demesticha and chief architect F. Vlachaki agreed that an accuracy of 0.05 m over the whole wreck area would suffice with photogrammetric control imposing an accuracy of 0.025 m.

Here the excavation task was focused on a 4 x 4 m trench located on the upper right area of the wreck (Figure 2) with main mapping task the daily recording of the findings position. The adopted methodology was constrained by factors such as the ability to utilize the pre-established local coordinate system, the speed of data processing (e.g. 8-10 hour processing ensuring that the position of each finding was recorded allowing for its next day removal) and the method's robustness with regards to its self-detection of erroneous points (e.g. points that have been moved unintentionally). In such a case, the best solution would be to establish a smaller network around the trench and to connect this with the previous coordinate system using bundle adjustment. Therefore, an initial bundle adjustment would use the plastic disks on amphorae rims as control for point coordinate transfer in the new location around the trench. Treating coordinates from a two-year past survey that has not been thoroughly checked together with point measurements on loosely fitted or even replaced plastic disks on the amphorae rims, is not a standard photogrammetric practice and it does carry a large risk. As this was the only feasible and economic solution available, the weighting scheme and geometry of the initial bundle adjustment were of high significance. In cases such as our, where the limited control pre-exists and is not tailor measured according to block shape, it is expected that the geometry will be poor. This fact in combination with the Photomodeler's claimed 'good' control point accuracy resulted in a remaining open issue regarding the method's quality.

3.3 Photogrammetric bundle adjustment

Nine control targets have been prepared (Figure 3) and inserted as deep as possible around the three sides of the trench leaving the fourth side clear in order to allow the divers to use the air lift for the digging process. The initial block adjustment was processed with 24 images acquired from an imaging range of 5 m and an approximate scale of 1:500. Eleven plastic disks with known coordinates were recognized from previous processing and subsequently utilized as control. The block geometry was poor due to limited control location at the two sides of the trench. Processing was implemented with the available Imagestation software with uniform control precision set at σ_{XYZ}= 0.02 m and an image measurement precision of σ_{xy}=5 μm (2 pixels). Table 1 provides sample results of one accepted solution where one control point was erroneous and rejected.

Vxy (μm)	0.001
RMS_{xy} (μm)	2.8
RMS_{XY} RMS_Z {CP} (m)	0.010 / 0.034
σ_o	4.0
σ_X / σ_Y / σ_Z (m)	0.010 / 0.011 / 0.031
Dof	513

Table 1. Bundle adjustments results

With regards to the camera model, photography and scale, bundle adjustment results suggest an acceptable RMS of 3 μm (~1.4 pixels) and a good planimetric point precision of σ_{XY}= 0.01 m and depth precision of σ_Z = 0.03 m. The a posteriori sigma naught suggests that initial precisions of input data were rather overestimated which can be attributed to the assumed control point and image measurement precisions. Main weakness of this project was the combination of the absent check points with the weak control point geometry; therefore these need to be reconsidered in the future. The 230 photo block is currently under processing in order to cross check the results obtained within Photomodeler.

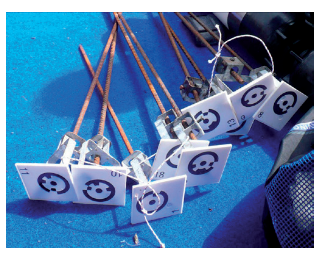

Figure 3: Control point targets

From that point forward, the daily survey of the trench covered only the trench area and its new estimated control points. It is noted that the combination of underwater diffusion and the lack of texture in the sandy bottom led to significant problems with regards to the tie point selection affecting the success of the automatic point extraction techniques. To address this problem a number of strips with coded targets were created and randomly positioned in areas with low contrast prior to the photography. For each new amphora a distinctive number of well-defined points were measured on its surface, as part of the bundle adjustment, and were subsequently passed to the architect who was manually positioning the model of the revolved amphorae, created as described in Demesticha (2010). Monitoring of the new estimated control points revealed displacements as well as slow movement, possibly attributed to the prevailing currents that were slightly but constantly pushing over protruding control points on the clay sea bottom. Again, reconsideration of control point type and measurement are open issues to be resolved in the next excavation period.

4. 3D MODELLING OF ARTEFACTS

Recording of the findings is one of the most significant tasks for the excavation process. Removed amphorae (with dimensions: height= 0.9 m and diameter= 0.35 m) are typically recorded with graphical techniques and 1:1 transfer from object to paper. With this elaborative techniques only one slice (or even half a slice in some cases) of the amphorae can be recorded. In order to improve this process and instead record the whole artefact, a number of techniques, highly advantageous over archaeological methods, have been proposed and utilised for full 3D modelling.

4.1 Laser scanning

Laser scanning utilizes a laser beam that is directed towards an object of interest by a dual-mirror system; the scanner measures the distance based on the diffuse reflection of a laser pulse from the surface to the object (Murphy et al. 2006; Ioannides et al. 2006). Different terrestrial scanners designed for scanning large volumes of objects such as buildings, archaeological sites, open mines, roads etc., characterized by their operational principle, they usually comprise expensive solutions regarding equipment and data processing. In our study we used the available Leica's ScanStation C10 laser scanner. The scanner operates based on the time of flight principle (maximum scan rate= 50,000 pts/sec, position accuracy= ±6 mm over 1-50 m working distances, surface noise= 2 mm). The scanner records a XYZ point cloud and the reflected beam intensity. Five stations were established all around the amphora in two phases by 180 degrees object rotation. Working range was set to 3-3.5 m and grid resolution to 1cm/100m. Therefore the scan data had a point density of 0.35 mm, a size of 2 million points and an estimated noise magnitude of 4 mm. The scan registration was done utilizing the four targets provided by the manufacturer and the available Cyclone software. Subsequently, the two independent point clouds were registered in a common coordinate system with an ICP-based registration (Besl & Mc Cay, 1992) and a discrepancy of 1cm. To remove noise from the point clouds a Laplace filter was applied in MeshLab software but this resulted in a detail and object geometry accuracy loss (Figure 4).

Figure 4: 3D object mesh of amphora's

4.2 Photogrammetry

In this test a large number of photos were processed for 3D modelling with open source software. Data acquisition time was a fraction of the laser scanner acquisition time (~1/6 to 1/8), which was important as the amphora had to stay completely wet during the process. The utilized camera was an uncalibrated 10.2 MPixel SONY A230 (array sensor: APS-C, size= 25.1 x 16.7 mm) equipped with a 18-55 mm lens. Photos were acquired with a focal length of 18mm and fixed focus during acquisition. Each phase included 36 freely acquired convergent images (two rings of 18 photos each) at a resolution of 3,872 x 2,592 pixels, sub-sampled at 2,000 x 1,128 pixels and processed automatically using Bundler (Snavely et al., 2006) and CMVS (Furukawa et al., 2010) softwares. Figure 5 illustrates a sample of the generated point cloud, noting that scale recovery was treated externally to the applied methods (e.g. scale was recovered with an adhesive measurement tape). This product was edited for background removal and ICP registration in Meshlab software, resulting in 195,000 'noiseless' intensity points. It is noted that CMVS open source software is based on a multi-image matching implementation and it only calculates points that are visible in at least three photos, therefore the implementation filters out any points that do not conform with its requirements; remaining points are considered as precise due to their high redundancy and their estimation from least square multi image matching.

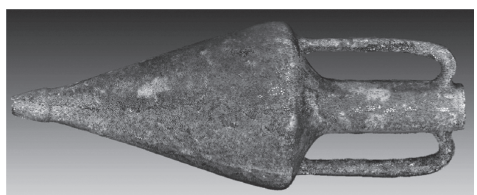

Figure 5: Complete photogrammetric point cloud

4.3 Comparison of techniques

Photogrammetry is by far the simplest and quickest method allowing for moving object removal in less than three non-stable images and posing no limitations regarding object position. The generated model presents law noise and it is easy to collect and process, hence the resultant object point density is not considered of high significance. It is, however, indicated that precise evaluation of photogrammetry and laser scanning would require ground truth (a model of higher order precision) and subsequent discrepancy estimation.

5. TRENCH MODELLING WITH COMPUTER VISION

In parallel to photogrammetry for amphora position estimation towards an 'as found' 3D model alternative methods have been tested. The vertical imagery used for bundle adjustment processing has been additionally processed with the aforementioned open source softwares (Figure 6). It is expected that additional photos with slight inclination would capture undercuts and thus provide an almost complete digital scene. The main, however, drawback of this implementation is that both scale and local reference system are arbitrary; this is expected to be resolved with control insertion. It is indicated though that this technique seems promising not only because it can automate the process and produce dense results, but because it additionally models the sea bottom on a daily basis, which is a requisite in the archaeological excavation context.

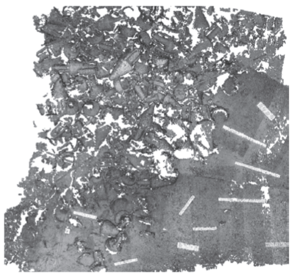

Figure 6: Automatically produced dense point cloud

6. CONCLUSIONS AND FUTURE WORK

The various implementations discussed in the Mazotos project can serve underwater archaeology in different modelling aspects. The presented products can support archives for measurement tasks that are not known in advance. However, the proposed approaches at this stage are not mature enough though to be undertaken by inexperienced users but they can be considered to be fast enough and precise in the application context. It is indicated that within a single afternoon, two people can suffice in order to process datasets of approximately 50 photos using bundle adjustment procedures for positional recording of the findings, photomosaic production and dense 3D point cloud generation of the trench. Underwater conditions significantly affect the quality of the photos; hence photography should be carefully addressed to avoid missing data collection areas or even dive repetition. An additional problem that needs to be addressed is control point positioning and mensuration to ensure stability in the sandy bottom. To further improve our derived products the following extensions and improvements are under consideration:

- Point cloud generation will need to incorporate semi or fully automated procedures for automatic 3D amphora positioning.
- Speed of product delivery is expected to be treated again by automating the test approaches that simultaneously minimize manual human error.
- Automatic registration for point cloud generation in a global coordinate system is required noting that control and scale recovery are essential for a metric outcome.

Expertise knowledge needs to guide the presented frameworks to avoid erroneous collection and data processing. Our present and future investigations are expected to incorporate processing of existing video sequences towards automated video-based capture and processing using for example optical flow.

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COMPARISON OF DOCUMENTATION TECHNIQUES FOR THE RESTORATION AND REHABILITATION OF CULTURAL HERITAGE MONUMENTS: THE EXAMPLE OF PYRGOS 'TROULLI' MEDIEVAL TOWER IN CYPRUS.

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KEY WORDS: Laser Scanning, 3D Digitization, Architectural survey, Conservation of cultural heritage

ABSTRACT:

Architectural and geometric documentation of a monument – and consequently of an entire archaeological site – is an important element both for its understanding and therefore for its restoration and rehabilitation. Thorough documentation is needed for a full comprehension of a monument. This constitutes a multilateral process, which can be briefly and generally described as the profound knowledge of the monument, which could be divided in various sections. These include the selection of the proper techniques of representation, the proper act of measurement and rendering, the reading and analysis of the edifice/artefact through its documentation, the clarification of its construction stages and chronological phases, considering if available the historical records, the archival and bibliographic sources etc. The important role that the graphic imprinting/representation of a monument covers for its understanding had been emphasized by Leon Battista Alberti in the VIth volume of his work *De Re Aedificatoria* (15th century), the first printed book concerning architecture.
In the present paper we intend to examine the two methods employed for architectural documentation and to conclude with a useful comparison between them. Finally, we denote its usefulness in the field of architectural conservation.

1. INTRODUCTION

1.1 General Information

Within the vast context of application of modern technologies in the field of archaeology and cultural heritage, the present paper examines the comparison of geometric documentation techniques at a medieval tower in Cyprus. The fragmentary nature of the tower and its distant position in a quite isolated location of the island rendered it unexplored all these years and it has often been threatened by total annihilation. A partial restoration was undertaken by the Cypriot authorities in the '90s (Hadjisavvas, 2003), but the lack of documentation of its preservation state prior to that intervention, prevents us from knowing how it was conserved until then. In 2007-2008 Kykkos Museum of Cyprus, undertook action oriented to the historical study, architectural survey, evaluation and rehabilitation of the monument under examination, aiming to preserve the site and to make it accessible to the public.

1.2 Previous Work

The use of 3D laser scanners for geometric documentation of cultural heritage is already well established, even though a lot of on-going projects are active in an experimental level, due mainly to the different and distinct nature of the cultural material to be documented each time.
Nevertheless, in Cyprus it could be considered as an innovation and its use and application consists a new field of interest for researchers, since only lately this kind of devices have been acquired by universities or institutional research centres.
The geometric documentation of a cultural heritage site, is defined as the action of acquiring, processing, presenting and recording the necessary data for the determination of the position and the actual existing form, shape and size of the monument in the three dimensional space at a particular given moment in time (Agapiou et al., 2008).
As Pavlidis et al. (2007) mention in their study, a complete digital recording of Cultural Heritage is a multidimensional process. Even though there is a large number of available techniques for geometric documentation of cultural heritage sites and objects, one should consider the following before choosing the most appropriate method (Pavlidis et al., 2007):

- The size and the shape of the object / site
- The complexity of the object / site
- The accuracy needed for documentation
- The diversity of raw materials

Moreover, as Pavlidis et al. (2007) mention, the cost of the application of digital documentation can be characterized as a vital and key parameter for selecting the documentation technique. Another factor that directly affects the selection of the proper documentation technique should be that of the nature of the structure or artefact to be documented.
The main techniques available today for digitization and geometric documentation of large objects, such as monuments, archaeological sites, old buildings, etc. can be tabulated into four main categories regarding the methodology applied. These are:

a) Empirical techniques or direct method
b) Standard topographic (geodetic) techniques
c) Photogrammetry
d) Terrestrial laser scanning

An empirical technique or Direct Method (Docci and Maestri, 1994) is a rigorous method of documenting a monument. It has a very low cost and does not involve any expensive equipment. The necessary measurements can be performed using either tapes or hand-held lasers. Empirical techniques applied to large objects can be characterized as simple topometric measurements. The accuracy, according to the complexity of the object, can vary a lot while it should be mentioned that the object is documented using only the characteristic points measured. Empirical techniques can provide not only 2D drawings, but also 3D (c.f. Agapiou et al., 2008).

The abovementioned methods b – d are capable of measuring in a non-contact way the monument, with a large number of points and provide a complete, detailed and accurate description of the object,

In geodetic measurements, the process involves the measurement of characteristic points of the monument / object using total station equipment with or without the use of reflectors. Total station can perform a very high accuracy, even less than 1cm. However, the use of only geodetic measurements in geometric documentation of a monument is avoided since it cannot provide a high density of points in a short time. Geodetic measurements can be used either as control points or trigonometric stations, or even to ensure that the documentation was sufficiently accurate.

Until the beginning of this century, photogrammetric techniques were the main technique for detailed documentations of large objects. Several applications have been performed successfully applying both photogrammetric techniques and geodetic measurements. Using 2D photographs, one, can extract under some constrains, 3D information and produce high accuracy measurements (e.g. for scales 1:100).

However, in recent years, laser scanning techniques have been widely used for documentation not only for large objects but even for small objects such as artefacts (c.f. Lysandrou and Stylianou, 2008). Laser scanners can measure in a short time a vast amount of 3D accurate points.

Combinations of such techniques have been applied for documentation of cultural heritage sites. Sophocleous et al. (2008) have used a combination of geodetic, photogrammetric and laser scanning techniques in order to produce a 3D accurate and realistic model of the Assinou Church in Cyprus. Guarnieri et al. (2004) have documented the main room in the Aquila tower in Buonconsiglio castle (Trento, Italy) in their study, in order to have not only a full documentation but also to examine the use of such techniques in Virtual Reality (VR). The potential of combining terrestrial laser scanning and close-range photogrammetry for documentation of Petra in Jordan is presented by Alshawabkeh and Haala (2004).

2. CASE STUDY

For the application and consequent evaluation of some of the above methods of documentation, the authors used as a case study a medieval tower located in the Tilliria area NW Cyprus.

2.1 Historical background

The tower is situated in the village of Kato Pyrgos, in the eastern part of Tilliria region (Nicosia District), on the NW part of Cyprus (Figure 1 and 2). Regarding, among other factors, the historical information about the architecture of the building, it is most likely that this tower had a military use, that of an isolated stronghold, forming part of the general defensive system of the island (Lysandrou, 2009). Its vicinity to the northern coast of the island, its location on a steep and rarely approached and inaccessible hill, its general planimetry and other peculiar characteristics lead to an interpretation of the structure as a Byzantine watchtower/stronghold of the medieval era. Most probably, it had been used in periods of both war and peace to serve the population of the area. Moreover, it is very likely that it used to communicate with other nearby strongholds, fortified cities and monasteries of that period in order to transmit a signal during, for example, an upcoming threat from the surrounding area or a possible attack from the sea. In this way, the signal was transmitted from one location to the other, covering the entire coastline of the island and reaching the mainland, where the ruling power was normally located.

Figure 1: Location of the medieval tower

Figure 2: The watchtower and part of the natural rock upon which it is located

2.2 Architecture of the building

The building is conserved only partially. Most of its vertical walls have been ruined and lost, except in one case, where the wall is conserved at a height of almost three meters. The whole superstructure is missing, which means that only assumptions can be made in relation to the upper part of the roofing and the overall height of the structure.

As far as architectural details and apertures on the main body of the edifice, one can only speculate, using foreign examples from outside Cyprus, since this is a unique case on the island. Part of the ground plan is missing as well. The preserved building consists of a polygonal ground plan with four sides, perpendicular to each other, forming angles of less than 90°. From the geometry of the building, the two sides on the missing part of the structure can be drawn, forming that way a close hexagonal ground plan.

The tower is built up with local volcanic stones of generally medium-dimension pieces stabilized with low-quality mortar. With difficulty, one can distinguish a coherent masonry employed for its accomplishment.

3. METHODOLOGY

In order to compare different documentation techniques applied in Cyprus until today for restoration and rehabilitation purposes, the authors have compared direct/empirical method, and laser scanning techniques both applied at the medieval tower of Troulli. The first one is the most widely method used in Cyprus for documentation of an archaeological site or a monuments while the second has been introduced to Cyprus only recently but still not systematically.

These techniques have been compared not only in matters of accuracy of the measurements but also in terms of cost, detail, and time. Finally, these techniques have been evaluated regarding their usefulness in restoration and rehabilitation procedures (see Chapter 5). The overall methodology applied is presented in Figure 3.

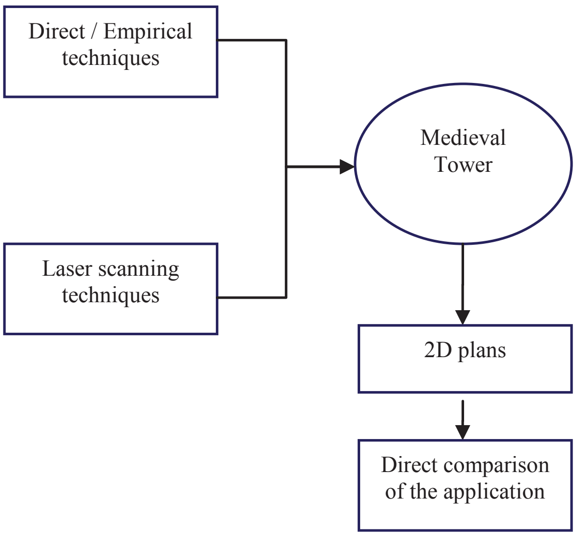


Figure 3: Methodology applied

4. APPLICATION

For a detailed and valid comparison between the different surveying methods applied, we are presenting in this chapter the direct/empirical and laser scanning techniques, the equipment used, the documentation procedures followed and the post-processing techniques applied. The photogrammetric method was used only partially, but was not completed as an application for the presented monument, in order to allow us to draw conclusions about its potential in comparison with the other two methods.

4.1 Equipments and in situ measurements

4.1.1 Empirical techniques or Direct Method: The first method applied for the survey and documentation of the monument is the direct one. This method consists of two distinct phases. The first involves the in-situ measurement and draft sketch of the monument. The second one will be described later on in the post-processing chapter and regards the graphic representation and rendering of the monument.

No special equipment is needed for the first phase. The work can be achieved using simple measuring instruments such as meters, metric gauges, decametres, squares a.o. or slightly more sophisticated equipment like laser distant meters and other instruments.

The first phase of the procedure consists of the in-situ work and the direct measurement of the structure. For this part of the work, a minimum of three persons is required. Some basic measurements were taken using a tape. A freehand sketch of the tower was drawn in order to plot the corresponding measurements. In order to simplify the procedure and shorten the transaction to follow a rigorous operational sequence during the course of the several stages, we therefore followed the subsequent scheme:

- sketch and draft detection of ground floor plan
- sampling measurements of ground floor plan
- sketch and draft detection of sections
- sampling measurements of sections
- sketch and draft survey of prospects
- sampling measurements of prospects

4.1.1 Laser scanning techniques The Leica ScanStation C10 laser scanner was used for documentation of the medieval tower (Figure 4-5). This laser scanner may scan up to 50,000 points per second, while the accuracy -as provided by the developer- is ±6mm/50m distance. The field of view of the Scan Station is 360^{o} x 270^{o}. Moreover the laser allows acquiring the reflected beam intensity and RGB colours. Tripods and the HDS scan targets are the main accessories of the instrument.

Figure 4: Leica ScanStation C10 laser scanner and one of the stations used

Figure 5: The north-eastern side of the edifice. Three of the special targets used for scanning this side of the monument are visible in the above image

For the documentation of the medieval tower, three scanning stations, in a distance of approximately 10m from the monument, were applied as shown in Figure 6.

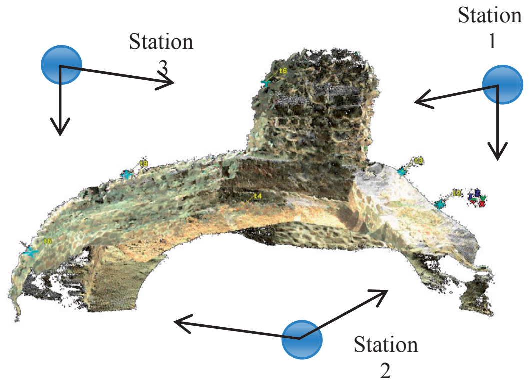


Figure 6: Laser scanning stations at a distance of 10 m from the monument

Using the special targets, the registration of the point clouds is possible. For scan data collection of the monuments the resolution of the scanner was set to an average grid resolution of 1cm in a distance of 10m. As a result of the application of the laser scanning technique, the entire tower was documented except from the ground plan. This could not be achieved since it required special scaffolding. However the boundaries of the ground plan can be drawn using the combination of the inner and outer measurements of the tower's sides.

4.2 Post-processing

4.2.1 Direct method/Empirical post-processing The second phase of the direct method consists of the graphic rendering. We did not proceed with classical manual drawing, but we chose the digital representation. The data acquired in-situ through the measurement of the monument was transferred in an AutoCAD environment. Since the original masonry of the building is somewhat slapdash and subject to later interventions, it was extremely difficult to measure stone by stone. The difficulty of this transaction is reinforced by the gnarled/rough place where the monument was built. Drawing of all the facades, sections etc. of the building were performed. Parts of the results are shown in Figures 7 and 8, where the two-dimensional drawings can be seen.

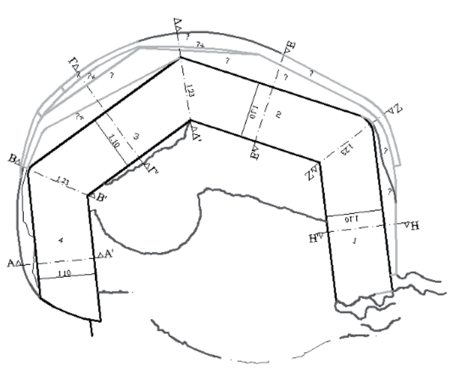


Figure 7: Ground plan and internal facet/view of the four walls

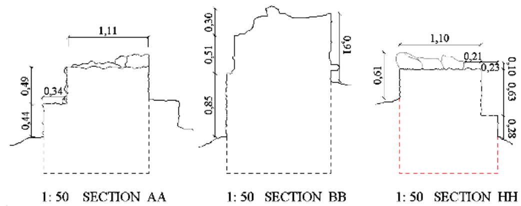


Figure 8: External facet/view of the four walls and sections

4.2.2 Laser Scanning post-processing

The post-processing of the laser scanning includes some standard procedure. At first, after the data are downloaded to the computer the registration of the point's clouds was applied in the Cyclone software.

The registration was performed automatically using the special targets. Afterwards, an ICP (Iterative Closest Point) algorithm was applied in order to achieve a highest accuracy of registration of the point clouds in the same software.

The relative accuracy of scans was up to 2cm (RMS) between the point clouds. After the ICP algorithm was applied the accuracy was found to be less than 1.5 cm. However, the accuracy of the registration can only be evaluated by using Check Points (CP) not used for the estimation for the registration parameters.

The next step of the post-processing is the automatic and manual cleaning of the data. This is a necessary step in order to minimize the noise which appears in the point clouds and to define a perimeter of the area of interest (Figure 9).

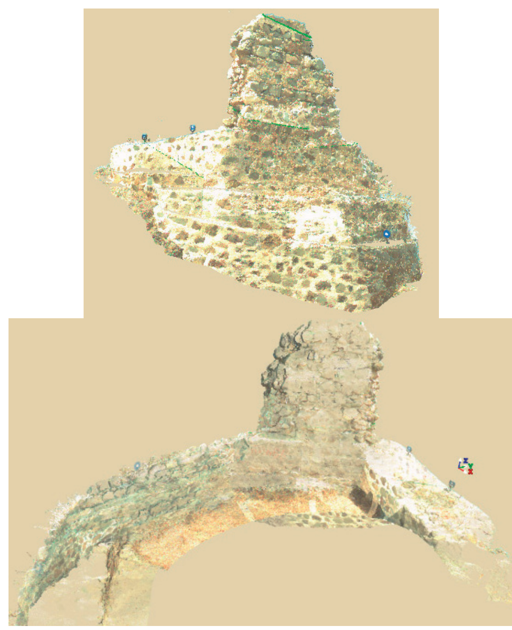


Figure 9: Final Point clouds

After the cleaning of the data the mesh procedure can be performed using all the points' clouds. A 3D mesh was created in the 3D Reshaper software (Figure 10). The basic problem of this procedure was the holes observed in the areas where it could not be scanned.

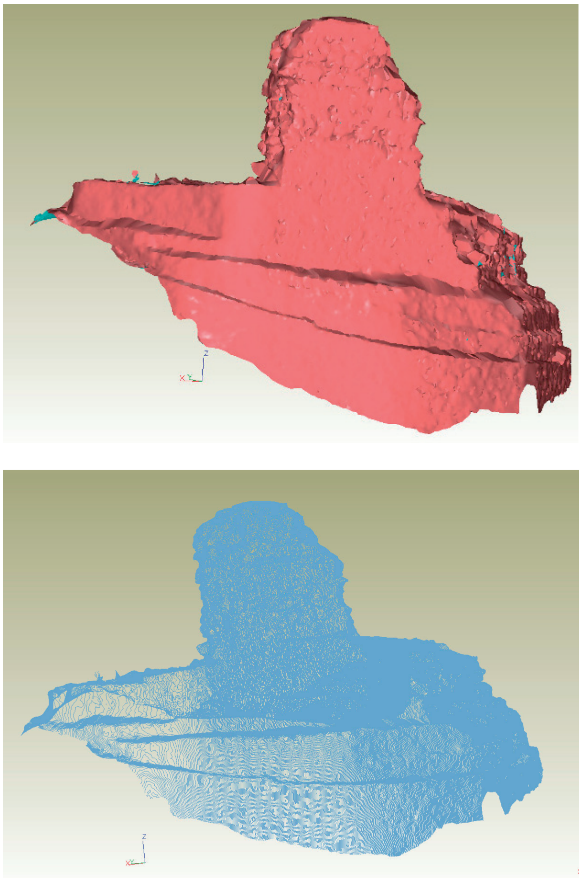


Figure 10: 3D mesh of the medieval tower

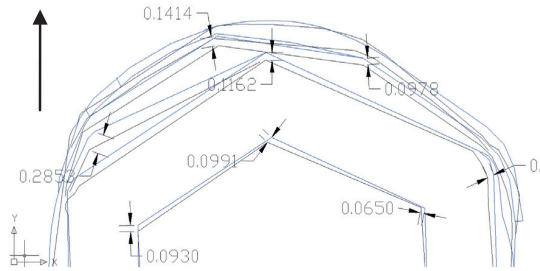
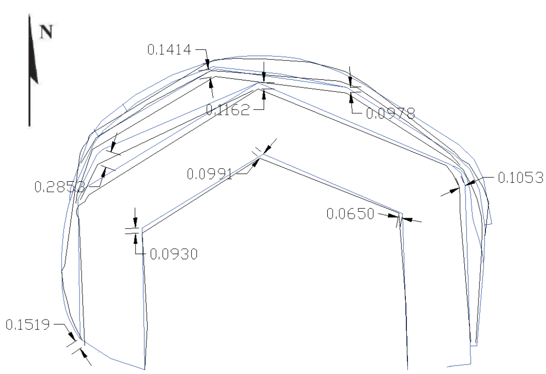


Figure 11: 2D plans from the direct / empirical method (blue line) and laser scanner (black line). For external outline is intended the northern side and for internal the southern one. The measurements indicate the absolute difference comparing the two methods (direct and laser scanner) for some characteristics points of the medieval tower.

5. COMPARISON OF DOCUMENTATION TECHNIQUES FOR PRESERVATION PURPOSES

An accuracy assessment was applied to the 2D plans of the tower, from direct and laser scanner techniques. Here the authors describe the comparison ground plan of the monument and its external and internal outlines (Figure 11).



Putting aside the problematic case of the presented edifice, as an overall evaluation of the methods used for its architectural survey, we denote that the most accurate way is the one realized via the use of the laser scanner as it was expected. It represents the most efficient method out of the two of them. The inside of the tower was well documented with direct/empirical method, although in the external façade, where the geometry of the tower was more complicated, the direct method was unable to provide a more accurate documentation. Approximately an error of ± 10 cm is observed from this comparison.

If we consider as primer scope of the laser scanner's result the documentation of the monument, we can determine as an indirect scope that of the usability of that result for the means of virtual restoration or rehabilitation of the monument and its environment. In this case, the accuracy the laser scanner documentation offers – even though differing only slightly in the presented project from the result given by the direct method of documentation – is still very valuable for the virtual reconstruction of the edifice, which is based primarily on the geometry of the structure. If this minimum accuracy is missing, the iconic reconstruction of the monument will be more difficult to achieve.

Laser scanner techniques can be combined with photogrammetry for a true texture 3D accurate result. Calibration of the camera and post-processing of stereo-photos should be performed using the appropriate softwares.

Although laser scanner equipment and software may have a higher initial cost than other methods, this is offset by its long-term use and useful life, as well as by the final accuracy of the scanned products. It must be emphasized that the laser scanner is a non-contact, non-destructive recording technology therefore it does not affect the monuments. Furthermore, laser scanners can be used for parts of the monuments which can not be reached, or in a larger scale for entire monuments located in areas difficult to access.

In addition, using the laser scanner avoids unnecessary travelling to the area of interest, in the case that a measurement is lost or not correct or even left behind, something that frequently occurs applying the direct method for documentation. Using laser scanner saves man-hours in all the stages of the procedure.

More over, the final result derived from post-processed data of the scanned edifice, being both topographical and architectural, can be used for multiple purposes and serves several different goals, from presentation purposes to educational reasons and most importantly for the preparation of accurate restoration

projects on a virtual level until their eventual and final implementation. The monument remains intact and undisturbed from the beginning of the documentation and study process until the final (and, hopefully, correct) decision about its future is taken.
However, scans may be made of any opaque physical object. Reflective or transparent surfaces may not be digitized very efficiently. These drawbacks could be eliminated by using and trying to enhance these new techniques in the architectural design processes.
In any case, what maybe is the most important part of the documentation is the use of the equipment and the post-processing softwares. The person should not in any case be a mere user/performer, but needs to have a certain knowledge concerning the architecture, abilities of observation and reading and interpreting the structural organism that he studies. In lack of these capabilities and scientific background, certain peculiarities that each monument presents are in any case lost forever. Here another issue emerges, that of the interdisciplinary collaboration on such projects, in order to obtain the best results.

6. DISCUSSION/FUTURE PLANS/CONCLUSION

The documentation of the medieval tower was a difficult case, since it was not easily accessible. Its rudimentary state of preservation, the incoherent masonry, the irregular shapes of the material used and other factors, rendered the presented project even more difficult, but a challenge at the same time.
Out of the two methods used for the survey of the medieval tower, laser scanning techniques were found to be the most appropriate and accurate. However the use of a laser scanner is not a panacea for the digital documentation. A synthesised methodology applied using either empirical or photogrammetric approaches can be very useful in some cases. This comprises one of our forthcoming projects, as well as the implementation of the method in different types of structures with more architectural ornamentations and detail in order to evaluate the performance of the equipment and the post-processing softwares.

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2D and 3D Data Capture Methodologies and Data Processing in Cultural Heritage

Part II

QUALITY IMPROVEMENT OF MULTISPECTRAL IMAGES FOR ANCIENT DOCUMENTS ANALYSIS

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KEY WORDS: Document analysis, deblurring, image registration, multispectral imaging, blind source deconvolution

ABSTRACT:

Multispectral imaging is widely used for the analysis of ancient documents, like manuscripts or printed books, affected over time by degradations. Document digitization is performed with a monochrome sensor (CCD or CMOS) and an optical filter for each spectral band (infrared, visible, ultraviolet). This allows to capture additional information with respect to common RGB imaging, revealing details invisible to human eye. The use of optical filters causes geometrical changes and channel-dependent blurring, due to different refraction indices and manual focus setting. Moreover, document manipulations cause alterations among the channel images. Then, if the purpose of the study is the virtual restoration of the document and not only its interpretation, elaboration of the multispectral images is required. In this paper we will present a methodology, tested on individual solutions, to preliminarily register the images in order to correct geometrical misalignments, and apply deblurring techniques to improve image quality for further document analysis, where sharper images are needed. Deblurring is performed with a multichannel approach, adapted to the case of multispectral acquisition. Statistical techniques of decorrelation are applied to improve the legibility of documents or to restore degraded features, extract individual context parts of the document, separate patterns as the main text from the background, or attenuate interferences due to the seeping of ink from verso-to-recto.

1. INTRODUCTION

Multispectral imaging is widely used for the analysis of ancient documents (handwritten or printed) affected by several types of degradations (Tonazzini, 2004; Lettner, 2009), which could be due either to ageing, atmospheric influences, inappropriate archiving and manipulations, and to the seeping of ink from the reverse side (bleed-through) or the transparency of text through the page (show-through) (Drida, 2006). Digital acquisition in different spectral bands (infrared, visible, ultraviolet) extends the document information with respect to common RGB capture (Martinez, 1996). The acquired information changes with the spectral band. Indeed, infrared and ultraviolet channels allow hidden details to be detected (Lettner, 2008; Easton, 2003), such as underwritten text in palimpsests (i.e., manuscript pages that have been scraped off and re-used).
Different optical filters and a monochrome sensor (CCD, Charge Coupled Device, or CMOS, Complementary Metal-Oxide Semiconductor) are used in multispectral imaging for data acquisition in several spectral ranges. Because of the different refraction indices and thicknesses of the filters, the acquired images can be misaligned and affected by blur (Brauers, 2008; Mansouri, 2005). Manual focusing operations make the capture of sharp images difficult, especially in the infrared range, where the text disappears and the low-contrast background is more visible. Moreover, document manipulations (i.e. page repositioning or leafing through during the recto-verso acquisition) alter the geometry of the acquired scene. Therefore, further image analysis tasks require a registration of the multispectral images (Lettner, 2007).
Image processing techniques are necessary to analyze the content of the document, either to remove unwanted background artifacts, to improve legibility of the main text or extract salient features, such as symbols, stamps or watermarks.
In our work we propose to align multispectral images by an automatic registration method based on the Fourier-Mellin transform (Reddy, 1996). After this preliminary step, deblurring techniques can be applied to minimize the blurring level, to improve the quality of the images and increase their suitability for contrast correction and noise removal.
Multichannel blind deconvolution (Šroubek, 2005) estimates the original (sharper) image and the Point Spread Function (PSF) from the blur convolution model:

$$\text{Image}_{\text{blurred}} = \textit{convolution}\,(\text{Image}_{\text{original}}, \text{PSF}) + \text{noise}.$$

The method is based on the processing of several input images (multichannel) and it works *blindly*, e.g. it does not require strong a priori information about the present PSF. The resulting restored image is sharper, with less noise and blur.
So far, this technique has been applied on multiple images from the same channel, with different focal settings. We try to extend this application to several channels, as in multispectral acquisition, assuming the knowledge of the PSF that describes the blur component in the image. After registration and deconvolution, we are allowed to analyze an image with improved quality and readability, relying on the fact that corresponding pixels in the different channels carry information coming from exclusively the same spatial locations. So multispectral acquisitions can be modelled as unknown mixtures of all the patterns that overlap in the document, so that blind source separation techniques can be attempted to separate them (Tonazzini, 2004). Such a strategy can be seen as a

* Corresponding author.

particular approach for a soft segmentation of the document content, where each pixel of the digitized document may belong to different document structures (Tai, 2007).

2. RELATED WORK

In this Section we provide a review of the deblurring techniques that we propose to apply for the improvement of the virtual restoration of ancient documents.
Deblurring techniques, often called deconvolution methods, aim to improve the image quality in terms of removal of image blur and noise reduction. The amount of a priori information related to the degradation, such as the size or shape of the blurring functions and noise parameters, affects significantly the success of deconvolution. When the blur function is known (non-blind deconvolution), many conventional approaches have been developed to recover the sharp image (see a review in Banham, 1997).
A more challenging problem occurs when the blur is unknown (blind image deconvolution). A state-of-the-art survey of blind restoration techniques is given in Campisi (2007). Most of the methods are iterative and minimize specific functionals. They involve regularization terms based on available prior information (i.e. image characteristics which can be expected) that assures various statistical properties of the image and constrains the estimated image and/or blurs. Regularization is required to improve stability. For images with sharp changes of intensity (e.g. characters printed on paper), an appropriate regularization is based on total variation, as first introduced by Rudin (1992). Minimizing such functionals preserves edges and fine details in the image (Chan, 1998, 2000; You, 1999). Since the blind case is strongly ill-posed, all the methods suffer from convergence and stability problems. If the images are smooth and homogeneous, an autoregressive model can be used to describe the measuring process. The autoregressive model simplifies the blind problem by reducing the number of unknowns. Several techniques have been proposed to find a solution to the blind case(Lagendijk, 1990; Reeves, 1992; Haindl, 2000). One way to overcome the difficulties of single-image blind deconvolution is to use multiple acquisitions of the same scene and apply the so-called multiframe blind deconvolution (MBD) techniques.
A typical example of multiframe acquisition with a single camera is capturing several pictures of the same object with slightly different focus settings. The lack of information at one frequency provided by a single image can be supplemented by the information at the same frequency from the other images. The blind restoration problem is thus simplified by the availability of different images. Research on intrinsic multiframe methods has been started by Harikumar (1999) and Giannakis (2000). Such MBD methods overpass the limitations of previous techniques and can recover the blurring functions just from the degraded images. The MBD theory was further developed by Šroubek (2005), who proposes a noise-robust method applicable to images misaligned by unknown shifts. Šorel (2008) recently considered the very challenging problem of shift-variant blind deconvolution. The above methods have been applied to images from the same band, with different sensor settings. In our paper we are addressing the issue of multiple images, obtained using several acquisition bands, as in multispectral acquisition.

3. MULTISPECTRAL IMAGING

We use a multispectral camera Chroma CX3 C1600E (spectral response: 350 - 1000 nm) composed, essentially, by a monochrome CCD camera that provides gray level images with 1,6 Mpx resolution, an 8-position filter-wheel and a Nikkor 35 mm lens (Figure 1). The camera is connected to a PC with a serial interface that allows us to control image acquisition and filter shifting. A infrared filter (IR) selects the band with wavelengths between 720 nm and 880 nm. An IR cut-off filter is used to block the infrared radiation in the acquisition of visible bands (Red, Green, Blue). The image at ultraviolet (UV) wavelengths is obtained by fluorescence of UV light, in the 350 - 400 nm range. For each filter shifting, it is necessary to put the image in-focus by manually rotating the ring of the lens, since the different refractive indices of optical filters alter the FOV (Field of View) and the focal plane. An example of document acquisition in the infrared, visible and ultraviolet bands is shown in Figure 2. The ancient document is affected by stains due to ageing, and bleed-through due to seeping of ink from the reverse side. The information selectivity across the channels is apparent: in the infrared bands the foreground text disappears and hidden stamps are visible, whereas in the ultraviolet band blur and contrast increase. The focusing, manually operated, consists in capturing images and subsequently adjusting the lens, thus the image quality can be compromised by an accidental error. The acquired images can be affected by blur and geometrical misalignment due to the different filters and the manual focus setting.

Figure 1: Multispectral imaging set-up.

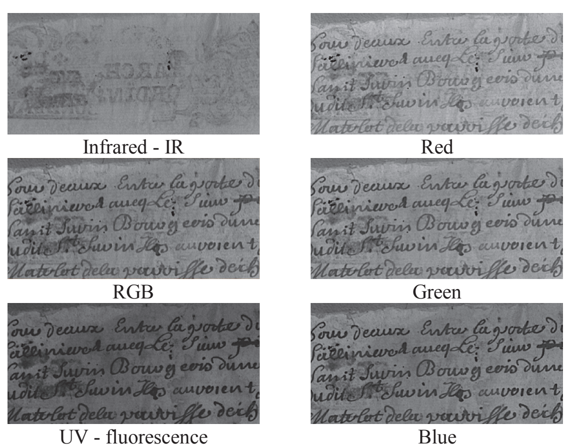
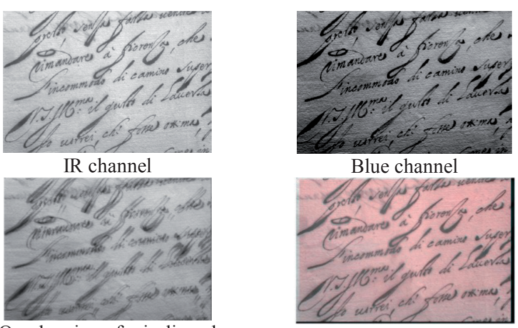


Figure 2: Document images acquired in different spectral bands.

4. IMAGE REGISTRATION

Image registration represents the solution to the misalignment of the images, happening during the manual multispectral data acquisition. The multichannel data are geometrically displaced due to different optical filters and to accidental movements during the acquisition. Among the possible automatic registration methods (Zitová, 2003) we apply a method based on the Fourier-Mellin transform. An assessment of automatic registration methods applied to digital analysis of historical documents is proposed in Bianco (2008). This method provides good results for registration of recto and verso sides of a document (Tonazzini, 2009). It has a high computation speed, showing robustness against both noise and illumination conditions, and it is particularly fit for the image acquisition in different spectral ranges (assuming that there are enough common edges in the images to be registered). The whole images are used to estimate the registration parameters and match them automatically. To relate each pixel to a precise location, one of the data images is taken as a reference, and all the others are aligned to create a data cube where all the information associated to one pixel is also associated to a fixed spatial location. We suppose that the document page undergoes rigid transformations in its plane. Moreover, we take into account the changing of scale due to the different FOVs of the optical filters. Then, we can assume that a similarity transformation is sufficient to model the misalignment: once a reference image has been fixed, the other images are registered by computing the translation, rotation and scale parameters. This method applies the Fourier shift theorem to recover the translation, and a phase correlation in the log-polar domain to obtain the rotation and scale parameters (Reddy, 1996). Once all the transformations are computed, the images are cropped to let them depict the same area and have the same size. In Figure 3, an example of registration of a document is shown: the shift between the infrared and blue bands, in this case, is due to the different filters used.



IR channel — Blue channel

Overlapping of misaligned images — Overlapping of registered images

Figure 3: Registration of IR and blue channel. The overlapped data before (evidently misaligned) and after registration are shown.

5. DEBLURRING

After the registration, the second problem to be tackled during the multispectral data processing is the insufficient sharpness of the acquired data. Figure 4 shows a typical example of what can happen if the camera focus is not properly set. The acquired data are then out-of-focus, blurred, and with no sharp details. The wrong focus setting is often present due to the manual manipulation during the data acquisition, especially in the infrared channel.

This type of image degradation can be modelled by convolution with a certain unknown PSF. This PSF, which characterizes the image blur degradation, can be different for different acquisition modalities. The blurring itself and the variations of the PSF shapes for the acquired multispectral channels make further processing complicated, because the next document analysis steps suppose either no blurring or at least the same PSF for all channels. These reasons led us to introduce a deblurring step into the proposed framework. Blind deconvolution is a mathematically ill-posed problem that, however, can be regularized either if more images of the same scene are available (multiframe blind deconvolution) or by using artificial markers in the data acquisition process for PSF estimation. The latter approach is based on the fact that a blurred version of the unit pulse (Dirac delta) represents theoretically the shape of the respective PSF. Although the unit pulse is not exactly achievable, the detected shape can be used as a very good first estimate of the PSF for its further iterative improvement, performed through the deconvolution method on chosen single images. Figure 5 depicts the acquired markers with three different radii.

In theory, a smaller marker means a better representation of the PSF. However, in severely blurred images, tiny markers are hard to detect due to the limited sensitivities of the cameras, and markers cropped from the image tends to be underestimated. Still it is possible to apply iterative blind deconvolution algorithms, such as in (Campisi, 2007), and use the cropped marker as an initial estimation of the PSF. One option to improve the estimated PSF is to use bigger markers. If we know the shape of the marker and have the corresponding blurred version from the image, we can apply simple algorithms for PSF estimation (Šorel, 2009). With the estimated PSF, one can apply standard non-blind deconvolution algorithms (Campisi, 2007) with sophisticated edge-preserving regularization (Rudin, 1992), which is especially good for images of printed text. Another option to improve the PSF estimation, and thus the whole deconvolution process, is to use multiple acquisitions of the same spectral band, but with slightly different focus settings of the camera. Then we can apply MBD methods such as the ones proposed in (Šroubek, 2005).

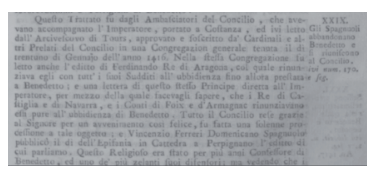


Figure 4: An example of out-of-focus blurred document image.

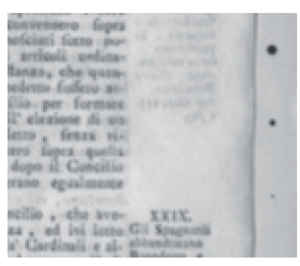


Figure 5: Artificial markers with three different radii introduced in an image. The out-of-focus blurring is apparent.

To improve the convergence speed of MBD, the cropped markers from the blurred images can be used as initial guesses of the PSFs. The disadvantage of this approach is the necessity to have at least two images in each spectral band, which slows down even further the tedious manual acquisition process. A promising method, which however must be still fully tested, would use multispectral images as individual channels in a type of semi-MBD approach. Each spectral image would be considered as a single image blind deconvolution problem with cropped markers as the initial PSFs. However, since the spectral bands are heavily correlated (e.g. edges are shared), regularization terms based on total variation have many features in common, and they can be formulated for multispectral images. A similar idea was proposed for blind deconvolution of multimodal medical images in (Šroubek, 2009). We foresee that, if properly modified, this technique can be applied to multispectral document images as well, and could represent a new direction for image deblurring.

6. DOCUMENT ANALYSIS

Ancient documents often appear as superpositions of different layers of information, such as the main text, additional texts coming from back-to-front interferences, spots due to ageing, and other possibly useful features such as stamps and paper watermarks. Not all the patterns may immediately be visible or identifiable.

Multispectral imaging captures a number of different channels, where some of the patterns we are interested in may be visible and distinguishable. Alternatively, one may select and compose different channels by digital image processing techniques, thus removing unwanted background artifacts or extracting salient features from the mixed information layers. The scheme in Figure 6 illustrates the process of modelling and processing, whose outputs are supposed to reproduce the unknown patterns.

In Tonazzini (2004, 2007) we adopt a linear, instantaneous mixing model, with unknown coefficients, for multispectral observations, and apply successfully blind source separation techniques to recover legible recto and verso text patterns from documents affected by diverse distortions. Among our solutions we include the ICA (Independent Component Analysis) approach suggested by Hyvarinen (2000). In the linear model, it is assumed that an N-channel multispectral scan produces an N-vector **x**(t) at each pixel t. Similarly, it is assumed that M source patterns, represented by an M-vector **s**(t), are superimposed to form the appearance of the document. Since we consider documents containing homogeneous texts or drawings, we can also reasonably assume that the reflectance of each undegraded source is almost uniform, and denote by a_{ij} the mean reflectance index for the j-th source at the i-th wavelength. Thus, the individual source functions $s_i(t)$, i=1,2,...,M, denote the quantity of the M patterns that concur to form the colour at point t. It is unlikely that this simple model is able to account for the true mixing process, especially where two or more patterns overlap and the mixing becomes nonlinear (Sharma, 2001). Also, the instantaneous assumption is often not justified, since the different observation channels can be affected by different blurs. Thus, even if we want to maintain a linear model, we should at least assume convolutive mixtures with channel-specific kernels:

$$x_i(t) = h_i(t) * \sum_{j=1}^{M} a_{ij} s_{ij}(t) + n_i(t) \qquad (1)$$

T = 1,2,…,T
i = 1,2,…,N

where $x_i(t)$, and $s_i(t)$, are elements of **x**(t) and **s**(t), respectively, and $n_i(t)$ is the i-th channel noise at pixel t. Function $h_i(t)$ is the blur kernel affecting channel i, and * denotes convolution. The N×M mixing coefficients, a_{ij}, must be estimated along with the functions $s_i(t)$ to solve the problem. Therefore, this becomes a problem of blind source separation from noisy convolutive mixtures, where the kernels $h_i(t)$ are often known. Classical ICA for instantaneous mixtures cannot be applied to the model of eq. (1), since the kernels $h_i(t)$ are different from a channel to another. ICA could only be applied when the blur operator is the same in every channel, i.e., $h_i(t)=h(t)$ for all i. The deconvolution procedure described in Section 5 aims at achieving this result even if the kernels are partially or totally unknown. To separate the sources, we can then apply a simple instantaneous ICA algorithm. Figs. 7 and 8 illustrate two examples of application of pattern separation and attenuation of degradations performed by ICA.

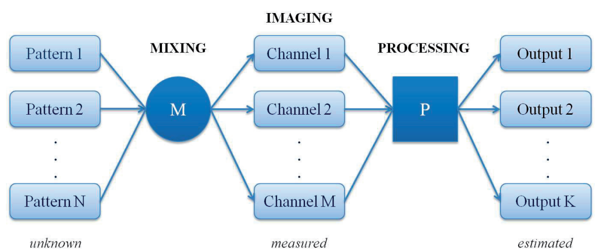


Figure 6: Superposition of different (unknown) patterns in multispectral imaging. Channel selectivity from diversity (measured) images can be translated into pattern selectivity. The outputs are estimates of the patterns.

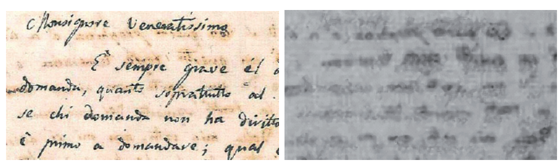


Figure 7: Recovery of bleed-through.

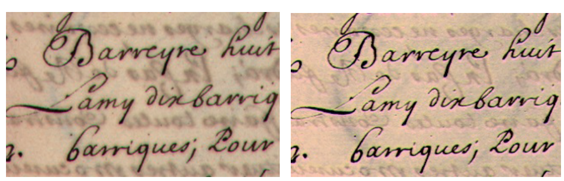


Figure 8: Attenuation of bleed-through.

7. CONCLUSIONS

Multispectral images can be affected by blurring due to filters with different refraction indices and to manual focus settings. We propose a methodology to deblur images acquired in different spectral bands, in order to perform a virtual restoration of ancient documents. Image sharpness is necessary to further image analysis tasks. Multichannel blind deconvolution is applied to a set of registered images of an ancient document affected by several degradations. A registration method based on the Fourier-Mellin transform allows us to compute the geometrical parameters to align the channel images to a specified spatial reference. After registration, deconvolution techniques decrease the blurring to ease the work of further source separation methods. Here we propose a deconvolution approach that gives a preliminary estimate of the PSF through the use of artificial markers, either processing the individual images or exploiting the whole multispectral data set. In the latter case, a new semi-MBD approach will be tested, where each channel is deconvolved individually, but the total-variation regularization terms are formulated for multispectral images. Finally, statistical techniques can be applied to attenuate degradations and improve document legibility.

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Short Papers

THE MULTISPECTRAL AND 3D STUDY OF THE OBELISK TOMB IN PETRA, JORDAN

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KEY WORDS: Thermal analysis, Multispectral photography, Laser Scanning, Photogrammetry, Cultural heritage recording

ABSTRACT:

The Obelisk Tomb is the first important façade that a visitor sees while entering to the archaeological site of Petra in Jordan. The rich architectural formations carry Egyptian, Hellenistic and Nabataean influences. The damage that was inflicted on this unique monument led us to study it applying a number of modern digital techniques including 3D scanning, multispectral photography with visible and near infrared images, and thermography. Our results clearly indicate that in addition to visual inspection and visible photography, such techniques allow a better examination of the existing damage in two and three-dimensions by highlighting certain important aspects of weathering causes, as well as shed some light on the causes of the damage. Plants are easily detected by the near IR imagery after contrast enhancement, while thermal imagery accentuates the architectural details of surfaces, showing clearly the edges and any damage they may have incurred. Superimposing different spectral bands much like in remote sensing proves to be a very helpful approach to study weathering damage.

1. INTRODUCTION

The Obelisk Tomb and Bab As-Siq Triclinium (1st century BC - 1st century AD), is the first major monument encountered when entering Wadi Musa on the way to the 1.2 km long Siq, the main gorge entrance to the ancient city of Petra. This complex facing NW is dominating the left side of the road, a few meters down from the Djin blocks. In reality, the Obelisk Tomb is separated into two monuments, stacked on top of each other: the Obelisk Tomb (upper storey); and the Bab as-Siq Triclinium (lower storey), Fig 1. The Obelisk Tomb (also known as 'Nefesh' Tomb) is named after the four obelisks that decorate the top of the entrance of the tomb guarding the rock-hewn cave tomb entrance and was used for burials. The lower storey, the Bab as-Siq Triclinium is decorated in a more classical style and was apparently used for funeral banquets as many such chambers in Petra used for memorial feasts in honor of the dead, a practice that was also common among the Greek and Romans. Through this variety and richness of the decorative and symbolic architectural elements, this complex reflects perfectly the spirit of the late Hellenistic architecture, where architects moved among different cultures create high artistic architectural formations, especially the Baroque nature of the rock-cut sandstone façades. Certainly these different historical architectural treatments at the same monument were not only decorative but they indicate how this family wanted to be seen for the eternity. It is possible; therefore, that this architectural formation may came from that direction.
A Mensi GSI 100 laser scanner together with a Flir B4 thermal infrared camera and a Canon 1Ds Mark III for the visible and near infrared (NIR) images were used to acquire both the metric and multispectral data. The acquisition of the NIR photography required a chase for a visible opaque Kodak Wratten 87 gelatin filter. All the recorded images were eventually draped onto the resulting 3D model. The previous experience of false color composition utilizing NIR paper films and conventional photography to try to enhance the damage and the material variations observed on part of the Palace Tomb Façade (Akasheh, 2000), carved out of Precambrian Sandstone, is adapted and extended herein over 3D models. The results showed that we can easily locate plant infestations no matter how small and even if they are not easily apparent to the naked eye. In addition, UV sensitive films allowed the detection of Limonite veins and infestations even when mixed with dust, clays and other sandstone types.
It is possible to acquire more easily such multispectral data using the faster and more efficient digital techniques. In addition to the acquired images in the field, we have created false color images that revealed more easily the damage and some of its causes, utilizing different bands from the various photos, very much like the Landsat bands utilized in remote sensing. The resulting images render some interesting results that are presented in this paper. The technique of draping either the obtained band combinations of false color images or the field photos onto the 3D model opens up the rendering to enhance the weathering effects and their damages for methods and techniques of cultural heritage documentation. In fact, it allows specialist to examine closer and better the problems threatening the monuments. The work reported next is focus on the Obelisk Tomb.

2. THE OBELISK TOMB

The Obelisk Tomb has several graves housed in it. The Tomb section is characteristic; mostly the floor is clear to the bedrock, the interior consisting of an approximately square chamber (5.80 m x 5.90 m, h. 4m) with a broad recess in the back wall in a form of rectangular arcosolium (2.9 m x 1.7 m, h. 3.1 m) starting 0.2 m above the floor, and decorated with 2 carved pillars (w. 0.49 m) crowned by a segmental arch, and two Loculi, with the approximate dimensions of 2.5 m x 1.25 m, h. 2.3 m, starting 0.12 m above the floor level, and carved on each side of the wall.

There is another grave (2 m x 0.5 m) in the floor towards the front of the chamber, parallel to the left side wall. The facade wall has a slightly raised band on both sides of the doorway and two splayed windows which emerge as slits on either side of the entrance doorway (Fig 2). The doorway width is about 1.35 m and is approached by four steps of 0.4 m width.

The façade (w. 16 m, h. 12.25 m) is remarkable; it is approached by a staircase on the left Fig 2, passing a cistern (2 m x 2.1 m). Across the top part of the Tomb façade there are four obelisks cut free from the rock behind magisterial obelisks, 'pyramids' (Nefesh) with the top part of each weathered away. The left obelisk, which is the longest one, has approximately 7 m height.

Figure 1: Obelisk Tomb (upper storey) approached by a staircase on the left

These obelisks are clearly influenced by the Ptolemaic Egyptian stylistic prototype approach. Between the centre pair in the plain rock faced behind the level of the four obelisks, there is a classical niche carved with a statue in deep bas-relief, with two pillars and anta-type capitals, entablature and a Doric frieze. This bas-relief is quite weathered and has lost its head. However, the four obelisks and bas-relief are properly symbolic representations of the five people buried in the tomb.

The lower part is plain, with a central classical order doorway. It is very weathered with little detail visible clearly. The two doorway pillars had anta-type capitals and the entablature had a Doric frieze (Fig 4). Generally the façade is too weathered for any tooling to be realized.

Figure 2: The Obelisk Tomb doorway, pilasters, and entablature

2.1 Chronology

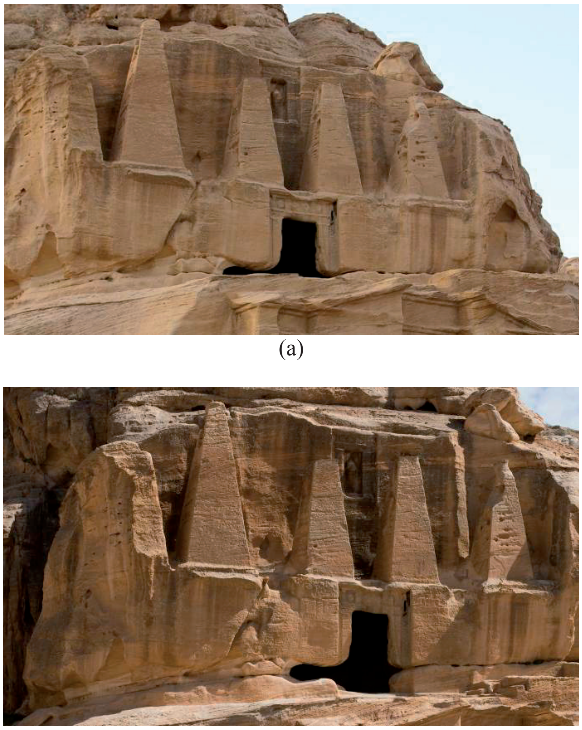
As with many monuments in Petra, it is unclear when these monuments were carved. Some scholars suggest the Obelisk Tomb is older than the Triclinium; others believe that they were built together dated to the mid-first century AD, according to the inscription opposite. This while across the road from them is an inscription in Nabataean and Greek, recording that Abdmank chose this site to build his tomb. This may or may not refer to the tombs across the road. Some believe that the bilingual inscription on the rock-face on the other side of the road, located with all the subtlety of a roadside advertisement, refers to both monuments. The longer Nabataean version reads: *'This is the burial place chosen by 'Abdmank, son of 'Akayus, son of Shullay, son of 'Utaih, for the construction of a tomb for himself, for his heirs and the heirs of his [heirs], for eternity and beyond: [he has made it] in his lifetime, in year ... of Malichus'.*

The Greek version is simply a summary: *'Abdomanchos son of Achaios has made this monument for himself and his children'*.

However, the Triclinium and the left and first right chambers are finished with neat lines tilted at forty and sixty degrees with a broad band of lines along the edges and lines on the ceiling parallel to the front wall. This tooling is identical with the tooling inside the Obelisk Tomb as indicated by McKenzie (1990). On the other hand, the recess of the doorway at the Obelisk Tomb is a problematic issue in this sequence. Here ancient Eastern traditions mix with Hellenistic architecture

2.2 Visual inspection of the weathering of the Obelisk Tomb

The frontal surfaces of all four obelisks are generally in a good condition except for the rightmost one, which is affected by Eolian weathering. A few alveolis or honeycombs can be observed on this surface (Figure 3). North western winds hitting the frontal surface seem to be responsible for this. The other three Obelisks are only slightly affected by this process. This is evidenced by the small cavity on the third obelisk from the left and the fact that all the frontal surfaces exhibit a certain roughness not common in freshly carved surfaces. The frontal side walls that flank the obelisks are harder hit on the front than the obelisks. More serious is the heavy erosion of the top of the obelisks. This problem appears to be due to down flowing water in combination with wind. The signs of water down flow are obvious on the left sides of the middle two obelisks. The impact of water and wind left these sides seriously honeycombed, with the tops being hardest hit. Thus the middle two obelisks have already lost their pointed tops. The top of the rightmost obelisk shows serious loss of material with granular disintegration as a result and is of the shortest height. While only a small portion of the top of the tallest left most obelisk has been lost, its top is in a relatively good condition but horizontal cracks and left side alveoli at the top threaten a similar fate to this top as for the other obelisks. It seems that as the north westerly wind hits the back surface of the façade eddy currents are created with result that the left surfaces and the top of the obelisks are hardest hit. The back surface shows some alveolar weathering (very high on the right side) with water down flow. The Niche in the center has retained its rectangular shape but the statue in its center suffers from granular disintegration with material loss. The right sides of the obelisks are in a better condition than the left, and are very similar in appearance and roughness as the frontal surfaces.



(a)

(b)

Figure 3a and 3b: Left and front sides of the Obelisk tomb

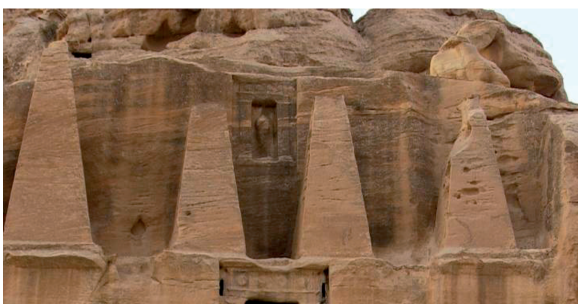


Figure 4: Statue and back face of the Obelisk facade. Water down flow on the surface, alveolar weathering on the right, with weathering granular disintegration and loss of form at statue

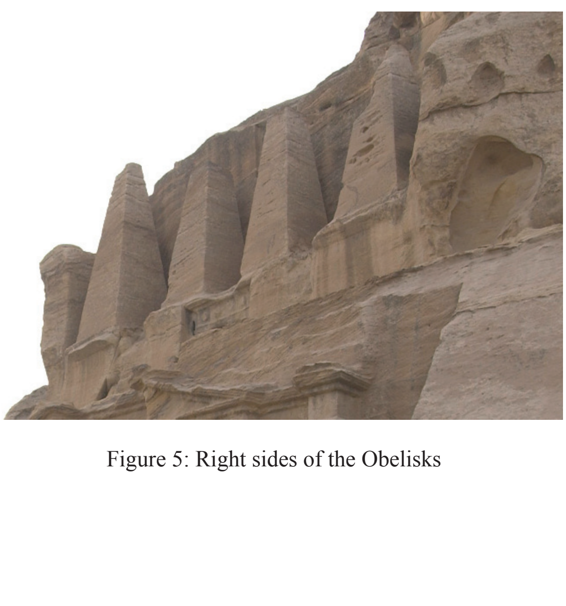


Figure 5: Right sides of the Obelisks

The horizontal surface (entablature) forming the base for the obelisks and topping the lower chamber below has lost some of its edges (double cornice) by water flow. Where complete loss of the cornice occurs, the effect of this flow is very high on the surface below (Figures 3 and 4). Water down flow along the surface below the cornice is very clear on both sides. The base of the leftmost obelisk is adversely affected by this process, since an angular crack, whose vertical inclined edge reaches right to the bottom of the obelisk and whose horizontal edge reaches the side protective wall and right though to the bedrock (Fig. 3b). The same figure shows serious loss of material at the doorway and its sides caused by capillary rise from the horizontal base in front of the entrance. The situation is made worse by the fact that a rectangular cistern and round hole have been dug in this surface and water collection during the rainy season poses an obvious threat, so much so that a big void is left on both side of the entrance.

3. 3D DOCUMENTATION AND MULTISPECTRAL RECORDING OF WEATHERING

3.1 Methodology

Our methodology relies on acquiring the various multispectral images separately. Thus Visible RGB photographs, NIR, and TIR images were acquired using the equipment described above. Initially we examined the weathering state both on the ground and using the visible photos. The results of this extensive analysis is given above. A visual examination of the TIR and NIR images followed. In order to combine the results of the three wavelength ranges we created we extracted the three bands of the visible photos, converted the colour NIR and TIR images to a grey image and then creating false image combinations from any three of the grey bands. This was accomplished using popular image software such as Photoshop. Visual examination of the false colour combinations allows us to see various materials in a different perspective than normally seen in ordinary colour photos. We also found that contrast enhancement of the false colours often discloses better info than the untreated images. At the same time we took 3D scans with the laser scanner and as such we were able to drape all the imagery we have obtained on the 3D model thus allowing us to see in the office all the imagery in 3D and better examine our results. We can vary the observation angle and zoom on particular points to analyze the results and attempt to correlate them to the weathering state.

3.2 Thermal Imagery

In earlier work we conducted a thermal study at the Djin Block No. 9 in Petra (Lerma et al, 2010), and we managed to correlate some of the results with high calcium content especially at the bottom of the south eastern side (Akasheh et al, 2005). Passive thermography has been used in many applications related to cultural heritage (Ludwig et al, 2004; Rosina and Grinzato, 2001; Rosina and Robison, 2002; Rosina et al, 1998). For the Obelisk Tomb, thermal images were taken at different times of the day. An example of these is shown in figure 6. The first thing that one notices is the fact that the images can enhance the architectural details. This is not surprising since the edges tend to warm up and cool faster than the bulk of the rock mass. In Fig. 6 some spots were selected to analyze the variation of temperature during the day. Figure 7 shows a chart of the temperature variation for six samples at different times.

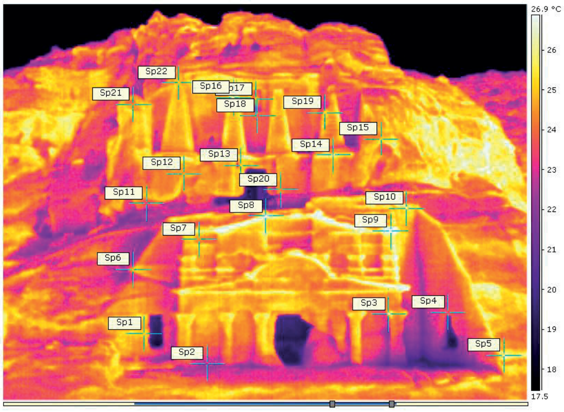


Figure 6: Spots measured on the Obelisk and Bab el Siq Triclinium

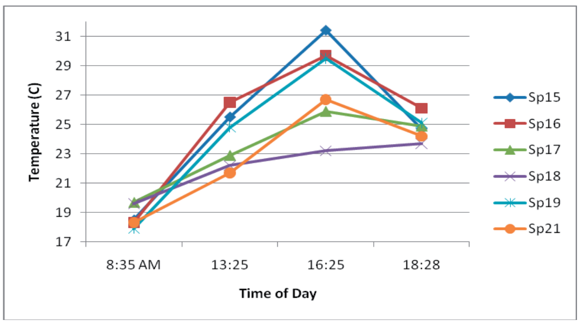


Figure 7: Temperature variations on some of the upper spots on Figure 6

Point	T 8:35 AM	T 1:25 PM	Delta T 1:25 PM	T 4:25 PM	Delta T 4:25 PM	T 6:28 PM	Delta T 6:28 PM
Sp15	18.5	25.5	7	31.4	12.9	24.7	6.2
Sp16	18.3	26.5	8.2	29.7	11.4	26.1	7.8
Sp17	19.7	22.9	3.2	25.9	6.2	24.9	5.2
Sp18	19.6	22.2	2.6	23.2	3.6	23.7	4.1
Sp19	17.9	24.8	6.9	29.5	11.6	25.1	7.2
Sp21	18.3	21.7	3.4	26.7	8.4	24.2	5.9

Table 1. Temperature of selected spots at different times of the day

In Table 1 the results for some spots are shown. Comparison of the temperatures at different spots shows the variation of temperature for these spots at a particular time of day from those at 8:35 am. The spots are highest in temperature at 4:25 pm. It is noted that Spot 15 has the highest temperature difference between 8:35 am and 4:25 pm. This surface to the left of the monuments has large alveolar holes. Attempts to correlate damage with this parameter failed to yield any consistent results. This is expected since earlier work on Djin Block No. 9, insolation was proved to be the less important factor in weathering, whereas water and wind were found to be more important (Akasheh et al, 2005; Heinrichs, 2008; Navarro et al, 2009; Cabrelles et al., 2009, Lerma et al., 2010). A more promising approach has been recently reported (Danese et al, 2010) using visual analytics, although some of the results are not definitive and there is a need to have more focus on the materials of the stone and the salt infestations. This is very important as the properties of the stone material and salt infestations should somehow be related to the NIR and thermal images very much like the yellow colour of Petra sandstones is due to limonite veins while deep red sandstones are attributed to hematite. Both are iron oxides and often the presence of limonite veins creates serious inhomogeneous bulk properties that render the stone more susceptible to weathering. We have previously correlated XRF data and Calcium content on Djin Block No 9 with the extent of damage and plan to study this situation on the Obelisk Tomb as well.

3.3 NIR Imagery and False Colour Band Combinations

NIR bands are very common in satellite imagery (Spot, Landsat, etc.) and have long been used in vegetation analysis and mineral identification form space. The application of this technique to archaeological objects, especially to paintings, has come more recently (cf. Garribba et al, 2001), partly because the cameras involved were very expensive, and because the cultural heritage community took some time to appreciate the value of this technique. Moreover, NIR paper films were subject to rapid deterioration with heat and had to be kept in cold environments.

Figure 8: NIR image of the Obelisk and Bab el Siq Triclinium

Nowadays, with digital imagery, new NIR sensors are available. In fact ordinary digital cameras can be modified to enhance their sensitivity in the NIR region. It is of common knowledge in satellite remote sensing applications that the NIR bands csn easily detect water as well as the chlorophyll in plants so that vegetation cover is more easily detected than by the visible bands. In fact the health of vegetation is easily evaluated by how extensive the NIR absorption due to chlorophyll is. Thus in Figure 8, the NIR image of the tomb is shown. A more useful image is created from the combination of different visible bands either with the NIR or the thermal image, yielding false colour images.

False Images with a TIR band are not very useful when in bamd combinations and the TIR are best examined separately. This is because of the low inherent resolution of TIR photography. However we are continuing to study this issue to perhaps optimize the use of such combination bands. Fig. 9 shows the combination of NIR, Red, and Blue bands. Contrast enhancement leads to Fig. 10. In Figure 9 it is very clear that vegetation is easily detected as is the case in satellite remote sensing (arrows). By contrast vegetation is not always as easily noticeable in visible images. Since vegetation growth is one of the means of biological weathering, NIR is an important tool for conservation of stone monuments. In Figure 10 the pitted surfaces (due to alveolar weathering (circle)) appear in two or more colours, while smoother surfaces appear in one colour even if weathering by smooth granular disintegration appears.

Figure 9: False colour combination of NIR, Red and Blue bands. Vegetation is indicated by an arrow. The lower detail shows how easy it is to see vegetation on the left side on land, as well as small plants on the monument.

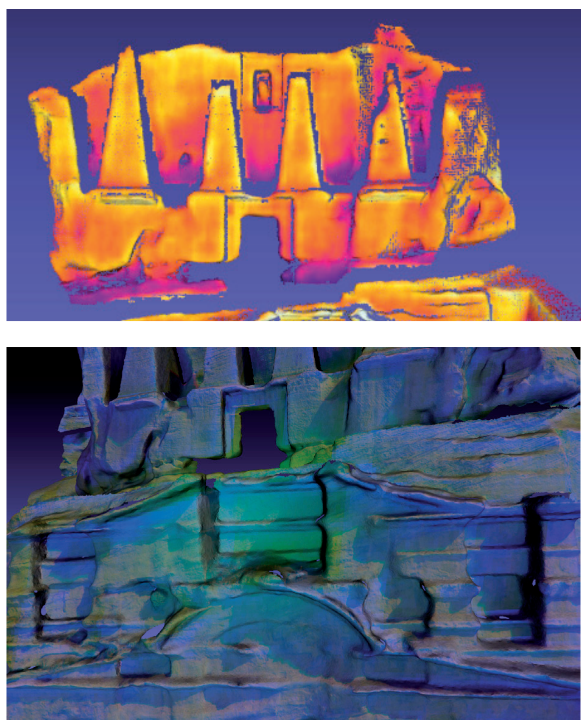
Figure 10: Stretched and enhanced false colour combination of NIR, Red and Green bands. Circles show some of the rough surfaces that appear in two colours. Rectangle shows area where one colour indicates a smoother surface. Arrows show small plants behind one of the obelisks.

Obviously not all the visible observations are enhanced by this technique. However, pitting and large aleveolies still appear in the false colour images with no advantage of one technique over the other.

3.4 3D modelling by terrestrial laser scanning and texturing of the multispectral data

With the advent of digital modern techniques for 3D acquisition, it has become possible to drape images on the three point clouds of objects. This allows examination of the weathering profiles in 3D even in the office, thus by far rendering the analysis of the conditions of damage of the monument easier. Figures 11-12 display the visible, TIR and the false colour (NIR, R, and G) images onto the 3D models, respectively. The advantage of visualizing the multispectral images in 3D is quite obvious. For one thing the visual examination becomes more realistic than examining flat imagery. The office worker can look at the monument and the false colouring from different angles and different resolutions thus reducing the time for field work. Another advantage that can be seen in Figure 12 middle TIR (NIR-G-TIR) and lower image (NIR-G-B) is that the band combination when draped over the model enhances even more clearly the architectural edge details and the damage they have suffered.

Figure 11: Visible image draped over the 3D model



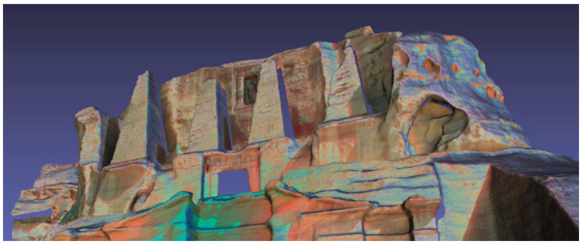


Figure 12: Upper image TIR image draped over the 3D model Middle and Lower Image is for a detail with the NIR-G-TIR band combination. In this case the architectural details are enhanced especially where edge damage is seen.

4. CONCLUSIONS

In order to obtain a correct representation of the existing condition over a large historical complex structure, it is necessary to plan, to introduce and to accept some specific surveys and representation techniques with support of different skills. Hence, it is crucial to choose the correct tools for a multidisciplinary analysis. Remote sensing multispectral imaging, ordinary photography and photogrammetry in addition to visual weathering examination lead to some valuable conclusions on the weathering profile of a monument.

.Documentation of cultural heritage requires the synergy of experts and technologies to study large complex areas such as the Petra Archaeological Park. The research presented herein allowed us to enhance the 3D documentation and 3D monitoring of the Obelisk Tomb owing to the integration of multispectral content which can play a major role in the documentation and the interpretation of the cultural heritage. In this particular research, the multispectral content included visible, near infrared and thermal infrared imagery. The series of thermal images were also used to analyse the thermal contrast and the behaviour of materials and alterations on the Obelisk tomb. While thermal imaging cannot relate solar exposure directly to weathering as it is not the predominant mechanism, it is still a useful tool to follow the extent of damage of architectural details especially when combined with other bands and draped on a 3D model. NIR imagery detects very small plant infestation which can be easily missed by field inspection and visible photography.

This kind of analysis is extremely useful to achieve a real representation of the existing condition of a complex object. However, among the several techniques used for the documentation of solid objects, the integration of multispectral content with 3D laser scanning shows that it has the potential to be of major value to the cultural heritage recording professionals. It is worth mentioning that this will enhance the capability to analyse deeply complex carved architecture in 3D from false colour images. The representations of monuments are enhanced to record weathering effects such as alveolar wind damages, flaking, cracks, and last but not least, moisture.

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VALORISATION OF THE DESIGN PROJECT. DIGITISATION AS A MEANS OF CONSERVATION AND KNOWLEDGE

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KEY WORDS: Digital Archives, Industrial Design, Digitisation, Cataloguing

ABSTRACT:

The paper describes the ongoing project of digitization of the archive of the famed Italian modeller Giovanni Sacchi. The main idea that drives the project is to create a digital archive that links heterogeneous data – sketches, technical drawings, images, physical models – referring to a single product in order to create an overall view of the design process and creative thought performed by various designers. Six renowned industrial products, of which Triennale di Milano conserves a wooden model of Giovanni Sacchi, have been chosen as case studies and all the related material has been retrieved, digitized and catalogued following the current Italian standards. The project of digitisation and the first results of the testing procedures are encouraging: the methodology has allowed to obtain high quality digital outputs and the Regional archiving system (SIRBeC) offers a great basis to build scenarios of access for the exploitation of data. The objective is to make the complete archive available at Triennale di Milano and in selected reference points for the off-line consultation, allowing to browse through the archive with technological and innovative devices: a pioneering system of consultation through the use of handhelds, table pc and the exploitation of augmented reality as a tool to enhance the comprehension of the digital data and to involve the visitors into an immersive experience.

1. INTRODUCTION

1.1 Context

Industrial design is certainly a result of the excellence of Made in Italy and is being pointed as one of the leading sectors of the Italian economy, where many interests are focused not only in terms of production and turnover but also for exploitation and promotion.
Furthermore industrial design can be intended as cultural heritage, witness of the industrial production and of the creative thought and meets nowadays the need to be shared with a wider audience, conveying not only the intrinsic value of the product but also the system of values in which that product was generated.
Many institutions have been creating culture for years around industrial design, promoting exhibitions and debates on the topic and offering spaces to showcase the culture of making. Triennale di Milano maybe represents the best outcome of this process with Triennale Design Museum that is together showcase, point of interest for visitors and tourists and means of learning for future designers.
The exhibition of industrial products is certainly the starting point for making culture on industrial design but it is also useful to analyze the context in which the product was created. In fact if it is true that the product of design is a work of art is equally important to analyze the mental process that generated it.
The acquisition by public institution, such as Regione Lombardia, of important collections and archives of designers makes today available a great number of documents, models, prototypes and drawings that can tell the story of a product: just to name a few, the Studio Museo Achille Castiglioni, filled with drawings, models and objects that inspired shapes and ideas, or the collection of wooden models of Giovanni Sacchi, that is testimony of the most significant products of Italian design.
The path, linear or less, which led from the first ideas to the final product remains today in the memory of those who collaborated with the great masters of design and is witnessed by the production of sketches, drawings, models and more or less detailed prototypes: on this richness of documentation it's possible to build a structured analysis of the design process, intended as useful advancement of the knowledge on design, learning tool for future designers and subject to dissemination to the wide public.
The digitisation of this documentation can be useful to allow the access to a broad audience, taking advantage of the great progress of information and communication technologies (ICTs) that are modifying the way in which people create, deliver, accumulate, and use data: digital libraries nowadays are enhancing the traditional ones, giving access to the information they preserve in a ubiquitous way, through the web and mobile devices.
The project we describe benefits by the great experience Italy has acquired in the last years into this field (Minerva, Minerva Plus, Minerva eC, Michael, Michael Plus, Athena) combining it with the excellence of the Italian design.

1.2 Aims of the Project

The project started with the assignment to Politecnico di Milano of the digitisation of some of the 312 wooden models of the large collection of the modeller Giovanni Sacchi, property of Regione Lombardia and now in custody at Triennale di Milano.
These models are stored but not exposed to the public because of lack of space, and the digitisation was intended as a way to show them.
From this first step, grew the idea to implement the project, collecting and digitising also drawings, photos, transparencies and models related to the analysed products, looking for them at the design offices and at the societies involved in the process of development and production.

The ongoing project we describe aims at reconstructing the development of these selected industrial products, designed by famed architects and designers, through a process of digitisation and cataloguing of all the related material to make them available to a broad public and to preserve the originals.
The aim is to allow the browsing among the digitised data that refer to a single design product, providing information related to the process of development as well as to the single document. The expected result of the project is the creation of an interactive system of visualisation of the digitised material, able to link heterogeneous data in reference to various products in order to produce an overall view of the design process performed by the designers.
A similar approach has been tested by Perseus Project (Crane, 1996), started in 1985 with the purpose to construct an "hypertext" (images, maps, Greek texts and videos related to locations and artefacts) for the study of the "ancient world and beyond" (Marchionni, 2000).
This goal will be achieved through two main steps: the first is the digitisation and cataloguing of the material, that while writing is almost completed, and the second is the creation of an interactive system of visualization of data.
In addition to this main purpose we can also list others of equal importance that we aim to achieve in the project development.
First of all the collection and rearrangement of all the documents that relate to the design process of the products, that often are forgotten in warehouses and drawers, bringing them to light.
The second is the digitisation of all this material, using the suitable technology, to create a digital copy useful for dissemination and conservation of the originals.
The third objective is the cataloguing of the documents into the database for cultural heritage of Regione Lombardia, SIRBeC, that is a very useful tool to maintain a record of them and a great basis for the creation of a consultation system.
The last aim, and perhaps the most challenging, is the definition of an innovative way of browsing among these digital data, taking advantage of the advancements in the technological field to allow an immersive experience of consultation.

2. FROM SKETCH TO THE PRODUCT

2.1 Methodology

2.1.1 Choice of the Objects: The ongoing pilot program we describe in this paper is limited to 6 out of the 312 wooden models of the collection of Giovanni Sacchi.
The choice of these products has been agreed with Triennale di Milano and is based upon two different motivation: first the ease retrieval of documentation concerning the products and second the value that they acquired in the history of industrial design.
Among the industrial products modelled by Giovanni Sacchi, we have chosen those for which a quite large amount of documents is available and useful to retrace the path of product development.
In particular, it is important to find documentation related to the assignment given by the companies to designers, objects used for inspiration, the first definition sketches of the product and all the drawings that were created with increasing level of detail until the final technical drawings. Furthermore we look for intermediate models and prototypes.

The objects we identified are:

1. Gibigiana Lamp, by Flos, designed by Achille Castiglioni (1980)
2. Tama Lamp, by Valenti, designed by Isao Hosoe (1970-1975)
3. 4870 chair, by Kartell, designed by Anna Castelli Ferrieri (1984)
4. 4822/44 Stool, by Kartell, designed by Anna Castelli Ferrieri (1977-1979)
5. Trattopen marker, by Fila, designed by Design Group Italia (1975-1976)
6. Rialto phone, by Siemens, designed by Design Group Italia (1977-1978)

Figure 1: Images of four of the analysed objects

2.1.2. Process and Approach: The project has been structured through three main sequential steps to be followed for all the design products and in particular:

1. Retrieval of documentation from the designers (or from the owner of the designer's archive) and from the companies that still produce or produced the product.
2. Digitisation of all the retrieved material following different methods according to the characteristics of the documents
3. Cataloguing of the digitised material into the Regione Lombardia cataloguing system for cultural heritage SIRBeC.

To these three main steps we can add the fourth activity that is the implementation of an interactive system of visualisation of the data, based upon the database used for the cataloguing.
The first step is the retrieval that, as stated before, is limited to the documents that testimony the process of development of the design project and, at this moment in time, it doesn't take into account all the documentation that relates to the commercial product (i.e. advertising, showrooms...): indeed the aim is to allow the reconstruction of the mental process that generated the final industrial products and this kind of documents is not relevant and if needed can be attached later.

The digitisation step requires the definition of different approaches because of the heterogeneous material that need to be acquired. We are speaking about large and small size drawings, photos, slides and transparencies, models and prototypes that need different technologies to obtain a digital copy.

With the due flexibility, the approaches we use are:

- digital photography for wide size drawings (technical drawings, wide posters, big sketches...)
- scanning of small size sketches and documents, slides and transparencies
- digital photography for models and prototypes
- 3D laser scanning of Giovanni Sacchi wooden models
- 360° photography of one significant prototype.

The digitisation follows the current Italian standards defined by ICCD (Auer, Cavallini, & Giffi, 1998), overtaking the top level A, required for large prints and conservation as an high-quality digital copy of the original. The specification of the parameters of digitisation will be given later while describing in detail the above mentioned approaches.
Furthermore, in order to assure a correct colour calibration and a useful dimensional reference every document is digitized with Kodak gray-scale and colour targets.
The third step requires that all the digitised material is catalogued according to current cataloguing standards and stored into the database for cultural heritage of Regione Lombardia, SIRBeC, that provides different records for any typology of document to be catalogued, distinguishing between drawings, photos, models and final prototype (in detail in chapter 4).
The scheme below summarizes the described steps and the different approaches to digitisation and to cataloguing.

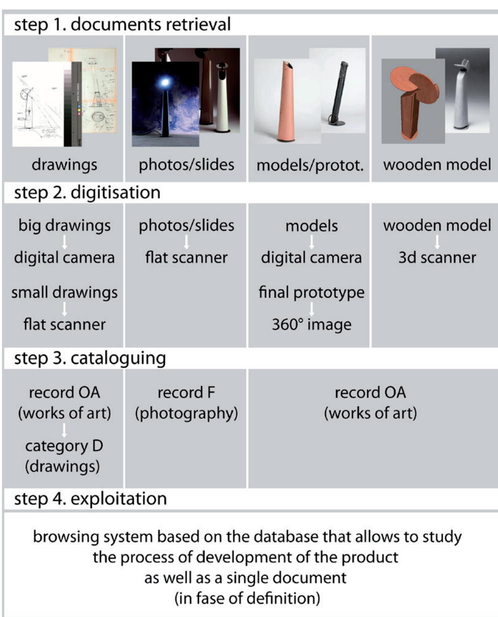

Figure 2: The four steps of the project

2.2 Chosen Products and Amount of Documents

As already stated, the project we describe is in progress and while writing we have completed the first three steps described for only four of the six identified objects, that anyhow count the greatest amount of available documents.

2.2.1 Gibigiana Lamp: The first product to be analyzed is the well-known lamp Gibigiana, designed by Achille Castiglioni for Flos in 1980 and still in production. Gibigiana is a table lamp that allows to concentrate an adjustable lecture light thanks to a movable mirror.
The choice of this lamp as case study is encouraged by the presence of a great amount of heterogeneous documents and material of different type that describe the process of development.
Studio Museo Achille Castiglioni, that is now part of Triennale Design Museum, stores original drawings of different size, slides and intermediate models, while Triennale di Milano preserves a precious wooden model of the lamp realized by the model maker Giovanni Sacchi, worthily considered today as a work of art and property of Regione Lombardia.
The exact amount of drawings, slides and models is described in the table below.

N°	Description	Size
22	Technical drawings	A1 – A0
25	Technical drawings	A3 – A4
64	Sketches	A3 – A4
6	Slides	24x36 mm
7	Slides	6x6 cm
4	Colour transp.	10x12 cm
4	Colour transp.	13x18 cm
18	Models	Various
1	Wood model - Sacchi	Real size
2	Prototypes	Real size

Table 3. Digitized documents for Gibigiana lamp

2.2.2 Tama Lamp: The second product to be analysed is the Tama Lamp, designed by the renowned Japanese designer Isao Hosoe in 1970, for the company Valenti and still in production.
Tama is a so called "*ready made*" lamp that is constituted essentially by a small tank for transporting liquids and a light bulb that produces a diffuse light through the polyethylene.
The lamp has been chosen as second product because Triennale di Milano in addition to the valuable wooden model in real size created by Giovanni Sacchi conserves also the product in the collection of Triennale Design Museum.
Furthermore the designer Isao Hosoe is still working and it was very easy to find material related to the lamp, created by the designer himself or by his collaborators.
The table below describes the amount of drawings and models that we retrieved.

N°	Description	Size
5	Sketches	A4
1	Technical drawings	A3
2	Technical drawings	A2
1	Sketch	A1
1	Technical drawings	A0
1	B/W Photo	13x18 cm
2	Models	Real size
1	Wood model - Sacchi	Real size
1	Prototype	Real size

Table 4. Digitized documents for Tama lamp

2.2.3 4870 Chair and 4822/44 Stool: The 4870 is a famed stackable plastic chair designed by Anna Castelli Ferrieri for Kartell in 1984 and that won the Italian price for industrial design Compasso d'Oro in 1987.
Designed by Anna Castelli Ferrieri for Kartell between 1977 and 1979 is also the series of stools 4822/44, that brought a strong formal innovation and an innovative use of polypropylene.
Thanks to the Kartell Museum that exposes all the production of the brand and conserves a great amount of documentation it was easy to retrieve material useful for the project. In particular we digitised 13 drawings and a wooden model for the 4870 chair:

N°	Description	Size
6	Technical drawings	A0+
4	Technical drawings	A0
1	Technical drawing	A3
1	Technical drawing	A2
1	Technical drawing	A1
1	Wood model - Sacchi	Real size

Table 5. Digitized documents for 4870

While for the series of stool the amount of documents is bigger:

N°	Description	Size
5	Technical drawings	A0
7	Technical drawings	A1
3	Technical drawings	A2
6	Technical drawing	A3
22	Technical drawings	A4
31	Sketches	A4
1	Wood model - Sacchi	Real size

Table 6. Digitized documents for 4822/44 stools

3. DIGITISATION. DETAILS AND PARAMETERS

3.1 Digitisation of Big Size Documents

The wide size technical drawings (A0 and A1 formats) have been acquired with a digital camera Canon Eos 5D MarkII (5616 x 3744 pixels), in RAW format, with a resulting horizontal and vertical resolution of minimum 240 dpi.
The choice of digital photography is due to two different motivation: the first is of economical order, in fact the relatively small amount of documents to be digitised, does not justify the purchase of a large high resolution scanner; secondly the originals to be digitised are frequently technical drawings that doesn't require a very high resolution as needed for example for precious ancient big size maps or similar.
The previous experience of the involved Photo Lab at INDACO department (Gaiani & Beltramini, 2003) has played a relevant role in the definition of the photo set that has been professionally designed to guarantee a correct and diffuse illumination and a perfect perpendicular angle between the drawings and the camera.
The high efficiency production of digital images has also been guaranteed by the well designed workflow that allowed to reduce idle times.
Gibigiana's 43 big size documents have been acquired in approximately 4 hours, with an average time of acquisition of 5 minutes, comparable to the time needed for the acquisition of the 4 documents related to Tama.
In the second day of digitisation, the acquisition of the big size drawings of Kartell products has been even faster with an average acquisition time of 3 minutes, thanks to improvements to the workflow and the presence of four persons, one more in respect to the first day of acquisition.

3.2 Digitisation of Small Size Drawings

The biggest part of the documents associated to Gibigiana Lamp and Tama Lamp and to Kartell products are small size drawings and sketches, usually not bigger than A3 paper size.
This type of documents have been digitized with a flatbed scanner in not-compressed TIFF format at a range of resolution from 300 dpi to 600 dpi, according to the real dimension of the original and to the complexity of the drawing.
Gray-scale and colour targets and a frequent colour calibration of the scanner has guaranteed high quality images and an accurate correspondence between the originals and the digital copies.
The small size originals of Gibigiana lamp have been digitised mainly at Studio Museo Achille Castiglioni to minimize the risks that might arouse from the moving of the originals to the Photo Lab while the drawings related to Tama lamp and Kartell have been digitised at Photo Lab, guaranteeing a greater homogeneity of the digital outputs.
The time of digitisation of the small size drawings is very hard to be calculated because the acquisition has been conducted in different places and in different moments.

3.3 Digitisation of Slides and Transparencies

Only among the documents related to Gibigiana lamp we have retrieved 21 slides and transparencies that have been acquired at very high resolution with a flatbed scanner in not compressed TIFF format.
The resolution chosen for the slides 6x6 and 24x36 is 4800 dpi while the transparencies (usually 10x12 cm and 13x18 cm) have been acquired at 2400 dpi.

3.4 Digitisation of Models and Prototypes

The aim of the digitisation of the models and prototypes is to reconstruct the process of development of the product from the first ideas to the final one.
The 3D scanning is without any doubt the best way to digitise a physical model but the process is still long and quite expensive: for this reason we have decided to limit the 3D scanning only to the precious wooden models of Giovanni Sacchi and to digitise all the other through digital photography.
In particular all the intermediate models have been photographed with a digital camera in a devoted photo set while the final prototypes have been photographed from different angles to obtain a 360° degree Quick Time VR image.
The above mentioned wooden maquettes of Giovanni Sacchi have instead been digitized at Virtual Prototyping and Reverse Modeling Lab at INDACO department as a 3D model with a laser scanner Minolta Vivid 910 and the clouds of points acquired have been processed to obtain a correct polygonal mesh.
The models have been successively texturized with the correct image to enhance the realism: the model of Gibigiana Lamp is a fully wooden model while the other models have also insertions of plastic components and electrical wires.

The obtained models have successively been exported as VRML (standard format for 3D) to allow a fast visualization with a common web browser with free plug-in.

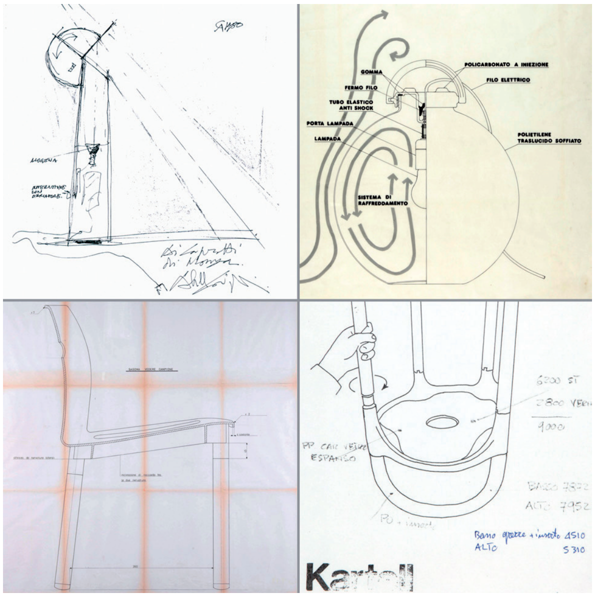

Figure 7: Drawings of the four objects

4. CATALOGUING OF DIGITAL DATA

The process of digitisation is maybe the most important part of the project but is also useful that all the digital data acquired are catalogued to be easily retrieved and visualized by potential users.

Every image has been indexed according to original labelling system of the studios and companies and while writing the process of cataloguing of the material related to Gibigiana Lamp is completed while the cataloguing of the material related to the other objects is in progress.

The informative system of Regione Lombardia (SIRBeC) is the basis of this process and allows the description of each digital image according to the typology.

SIRBeC (Sistema Informativo Regionale dei Beni Culturali della Regione Lombardia) is the cataloguing system for cultural heritage of Regione Lombardia (Degiarde, 2007) that allows the creation and management of databases, the description of the digitised documents and the visualization of the stored information on-site and on-line.

In particular the digital data acquired respond to two typologies: works of art (paintings, drawings, sculptures, fabrics and furniture) and photographs (photos, slides and transparencies).

All the drawings, the intermediate models, and the final prototypes have been catalogued according to the record OA (Opera d'Arte – Works of Art) that describes all the handmade production with an artistic value, while photos, slides and transparencies have been catalogued with the record F (Photographs).

The SIRBeC system provides also a record Design (DES R.L.) that describes the overall project behind an industrial design product, the related documents, the subsequent restyled editions and the information about the author. This record has been recently created by Regione Lombardia and the project represents a good opportunity to test it.

As stated above the process of cataloguing of the documents related to Gibigiana is concluded and the regional database now contains 180 records all linked to the record of the product (Design record).

The records created are linked together to allow browsing between them, following step by step the process of development of the design project or selecting the images according to the desired criteria.

Through the browsing of all the acquired material it is now possible to follow the development of the design path related to the product and to explore its evolution, or identify rethinking of the author, particularly in the large amount of sketches.

The cataloguing is a long process that requires long amount of time to be completed and in particular the creation of the 180 records related to the first object required about 90 hours of works of a trained person.

5. FIRST RESULTS AND CONCLUSIONS

5.1 First Results and Remarks

The project we have described is not concluded but the first results are encouraging: the methodology has allowed to obtain high quality digital outputs in a short period of time and the Regional archiving system (SIRBeC) offers a great basis to build scenarios of access to digital images, 3D models and to connected descriptions.

The 180 records created for Gibigiana Lamp now allow to browse into the database, following the process of development of the product or to browse searching by typology or following other criteria.

Sometimes it's even possible to detect Castiglioni's attitude to draw on existing object and his ability to integrate them into a coherent and harmonious shape that makes him a *bricoleur* designer (Levi-Strauss, 1962), half way between artist and designer. By the way the user could identify hints and recalls to other objects that the designer would have developed later in his career.

This opportunity is useful not only for researchers and scholars that are conducting researches on Castiglioni's work but also for future designers who can profit by a *mind-on* and *hands-on* approach towards the culture of design project.

A similar result will be obtained for Kartell objects that count a great amount of documents and allow an interesting browsing between the drawings.

For the other three objects the condition is quite different because the amount of material available is considerably less and all the drawings and related material are not conserved into a museum or museum-like office, but in a still operating design office.

It's important to remark that the project we discuss is not only a digitisation and cataloguing project but it is an attempt to go beyond the mere digital acquisition, shifting the attention from how to what is digitised.

The final aim of the project is not the digitisation and the cataloguing themselves but is the reconstruction of the process of development of six famed design products, bringing to light the cultural contents of the drawings, models and photos. They conserve in fact a great knowledge in terms of creativity, technical ability, process and communication that is worth to be rediscovered and disseminated.

The project is still half of the path and it seems untimely to judge the preliminary results but we expect to complete the first three steps in three/four months, by the end of 2010, according to the availability of the material related to the last two objects.

5.2 Future Works

At the moment a new campaign of digitisation is being carried out, including into the project the last two objects mentioned at the beginning of this paper.
The expertise developed during the first part of the project will certainly allow a faster implementation of digital data, developing a wide and complete database of images and related descriptions.
Following the current European Copyright Directive (European Commission, 2001), the digital images would be partially published on line on the regional portal Lombardia Beni Culturali and on the Italian portal Cultura Italia (Caffo, 2008) that refers to the Europeana European system. In particular it's important to operate a distinction between the documents that are conserved into a museum, as in the case of Studio Museo Achille Castiglioni, that can be easily identified as cultural heritage, and the documents that are property of still operating design studio.
The complete archive will be available at Triennale di Milano and in selected reference points for the off-line consultation, allowing to browse through the digital images with technological and innovative devices: the ambition is to create a pioneering system of consultation through the use of handhelds (smart phones, booklets and slate pc), table pc and the exploitation of augmented reality as a tool to enhance the comprehension of the digital data and to involve the visitors into an immersive experience.
The exploitation of the acquired data with advanced technological devices is still an aspiration and it will depend on several issues: first of all the final quality of data, secondly possible future funding to support the use of advanced and expensive technologies, and finally the interest that the project will arouse among the design community and the stakeholders.

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DIGITAL SURVEY FOR THE STUDY OF INTANGIBLE "TABARKINIAN" TRACES: THE CASE OF CARLOFORTE IN SARDINIA

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KEY WORDS: Tabarka, Digital Survey, Urban Survey, Carloforte, Sardinia, Architecture, Laserscan, Nueva Tabarka, Pegli

ABSTRACT:

In the Mediterranean area the richness of the relationship between people, art, architecture and urban settlements is articulated in an incredible mosaic. In this research the focus is set on the people who named themselves "Tabarkini" and on their settlements, especially on the "sense of place" produced by their towns on the observer. Visiting the town of Carloforte it comes out quite clear the impression to be in a town from the northern coast of Liguria more than on an island in front of the Sardinia Island. An articulated story has brought this population from Pegli (Liguria) to Tabarka (Tunisia) and to from there to Sardinia and on the small island of Nueva Tabarca in Spain. Behind the story of this people it's possible to read a story of urban settlements: which has preserved certain characteristics everywhere in the Mediterranean area, so that it is easy to feel the mood and the suggestions from each of the places touched by this migration, but it is difficult to identify the elements producing these sensations. A confrontation about the house typologies and of the urban pattern is still missing. To put in evidence which are the constants and the variables in these settlements and what makes these places what they are; this project has choosen to operate starting from a detailed survey and documentation campaign. The contemporary technologies based on laserscan and digital imaging have been used to develop a rich archive of information and to start the analysis about these Mediterranean settlements.

1. HISTORICAL BACKGROUND

In the mid 15th Century the Genoese had the control of the North Africa coast, they had obtained from the Tunisian Bey the privilege for fishing and for trading the coral along the coast of Ras Ajebel. This situation brought the creation of a more stable situation in that area, with the raise of a spontaneous settlement where it was possible to distinguish houses around a church, warehouses and a small walled city with a tower defending the colony from the pirates.

In the first half of the 16th Century the Spanish Crown began a military campaign in this area in order to hold back the Muslims. Tabarka, placed in a location highly considered for its richness in coral, has became the "center" of the Christian-Muslim rivalry. Here Spain wanted to establish there a strategic "border". In 1547 the first contract was signed between the Spanish monarch and the Genoese families of the Lomellini and of the Grimaldi. In 1560 is dated the renewing of the exclusive agreement with the Lomellini di Tabarka. The agreement allowed them to settle in the island with a presence legally defined by a concession about fishing and coral trading. In change they had to pay to the Spanish Crown the tax of a "fifth". They had the right to appoint a Governor of the island, who had to swear allegiance to the Catholic King and to rule according to the laws of Castile. Then a fortress dedicated to St. George was built on top of the island. So it began a two Centuries period of Spanish government, someone (like the Ligurian Society of History) has defined it as a "community-garrison of fishermen, craftsmen, soldiers and religious".

During the 17th Century, following the economic operations of the Lomellini Family, a large part of the people living in Pegli, near Genoa, migrated to the Tabarka Island. They were sent there to work as coral fishers and they colonized fully the small island. In the following century Tabarka became overpopulated while the coral reefs decreased. Moreover the population began to have trouble with the pirate incursions and with the local Governor. In the middle of the 18th Century, King Carlo Emanuele III di Savoia decided to offer to the population the opportunity to migrate to the southern part of Sardinia, to continue their work in a new completely uninhabited land, called San Pietro. There were two reasons for this offer: on one side it was an attempt to support the repopulation of the Sardinia Island, where people were reduced at that time to almost 300.000 units. On the other side it was the opportunity to block the pirate's presence in the San Pietro bays.

The colonization of San Pietro was done in few years, and the new town, named Carloforte, was built according to plan of engineer La Vallée.

A complex history of kidnapping and of slavery followed, in which a large part of the population from Carloforte and Tabarka were taken by pirates and sold as slaves on the Tunisian market.

The town of Tabarka was completely destroyed. Part of the kidnapped people were set free by the efforts of various European countries, and between the end of the 18th Century and the beginning of the 19th Century, they all came back from their slavery.

Figure 1: An ancient picture of the Carloforte waterfront

They partially went back to Carloforte, partially to Calasetta (on the opposite side of the gulf, in front of San Pietro Island) and partially to a new founded town, Nueva Tabarka, an island in front of the Spanish coast.
Up to now, the studies brought on have underlined the continuity in historical, linguistic, economic, sociological and cultural development of the settlements of Carloforte, Calasetta, Pegli and Nueva Tabarca; this proves the sense of affiliation of their inhabitants to a unique community.
Therefore it is presumable that this heritage has expressed itself also in the shapes of housing, in particular in the formal, constructive and typological characters of the residences and of the fortifications. All the centers of new edification, infact, were realized on the urban design made by military engineers and subsequently edified by the colonists with constructions belonging to their traditions. This aspect isn't secondary inside the general dynamics that have interested the new-built settlements following the so-called "tabarkinian diaspora", but it hasn't been sufficiently investigated yet. The research project developed in partnership with the Spanish team, aims to recognize the fundamental characters of the tabarkinian architecture, its constants and variables.

2. THE PROJECT

2.1 Tabarkinian traces: from intagible to tangible

The historians define the so-called "tabarkinian house" as a building made of stone, with square plan, one floor, covered by a single pitched roof. But there is a lacking of confirmation on the Tabarka Island, from which the name of this building typology takes origin; thus it is possible to find some examples (commonly called "baracca") in the rural environment on the Islands of San Pietro and Sant'Antioco in Sardinia. It is moreover presumible that these small buildings were the house-type in the urban environment.
Nowadays in Tabarka only the fortress of San Giorgio and the residue of some minor buildings remain to testify the presence of a town. The original documents about the settlement are not descriptive enough to give a clear image of the place and to allow developing any direct reconstruction hypothesis. With the exception of the castle, planned by military engineers of the Crown, the structure inherited traces of the settlement and existing buildings, where houses were built by the settlers themselves. The used type of housing should meet the logical constraints of simplicity, economy and functionality, using a models coming from the rural origin in a traditional way with a choice of easy self-construction to realize the "baracche".
While in Nueva Tabarca the "baracche" actually form the urban structure, in Carloforte a different economic situation and a very close tie-up with the "motherland" have induced the transformation of the original model according to the example of the Genoese building trade. At the same time, in Carloforte, It is easy to find practical and aesthetic solutions in arts, architectonic and urban solutions coming from the same heritage. The first step approaching this research is to gather the existing studies and start an articulated survey campaign to develop a clear and solid base of knowledge. .

2.2 Project development

Planning an investigation about urban and architectural features, the towns of Pegli, Tabarka, Carloforte, Nueva Tabarca and Calasetta show very different conditions:

- Pegli has been transformed after it has been blended inside Genoa's urban pattern.
- Tabarka shows only poor remains of the town, while the fortress is still standing and considered a military area.

Figure 2: The overall scheme of the research approach

- Carloforte shows a very interesting town asset with two different urban patterns: one in the planar part of the town on the waterfront and another used where the buildings have grown over the relief in the northern part. The transformations of the original housing typology are often heavy, but it is still possible to find well preserved or partially preserved samples.
- In Nueva Tabarca and Calasetta the typology used for the agrarian settlements is applied to develop the original structure of the town, with simple but still well readable solutions.

The target of this project is to find constants and variables in the architectonic and urban environment. This is to be done according to an articulated development process, where the entire urban context will be analyzed. The investigation will take care of some "relevant" elements, like the environmental sections, the overall structure of the town plan, the study of the cartography and of the previous investigations done. Then it will be necessary to move to the interpretation of the characterizing details, the chromatic features and the visual "noise" caused by disturbing elements.
To operate this investigation the tools will be the photographic survey, with a further image analysis to focus and to extract specific trademarks, and the three dimensional survey operated with laserscan technology, so to produce a complete detailed three dimensional image of the whole town, with all its meaningful features. Starting from these data, a simple and complete database will be developed, useful also to organize the base information for the research group. This database will be also the base for any further study and analysis.

3. APPROACHING TO THE THEME: CARLOFORTE

3.1 Digital survey

After a first extended phase dedicated to inspection and sources gathering, a survey campaign in Carloforte has been done in June 2010, basing the whole work on laserscan technology. A classic survey scheme was adopted, using a Phase Shift Scanner, a Cam2 Faro Photon 8080, supported by a specific topographical network. This kind of scanner works very fast, with a very good accuracy even on the long distance and it is well suitable to perform urban survey in a small town center like Carloforte.

Figure 3: The laserscan at work in the town centre of Carloforte

Figure 4: A plan of the surveyed areas in Carloforte taken from the survey sketchbook.

The topographical network, working as connection for each single scan is a fundamental step to allow quicker procedures and to fully benefit the laserscan characteristics. The laserscan campaign has covered the whole town center between the "via XX Settembre" at the South, the Civic Museum at the North, the sea at the East and the church of the town at the West. This has produced a good coverage of all the main aspects of the town, comprehending both the regular and the non regular urban patterns, from the entire building to the architectonic details. It has been created a complete three dimensional image of the town, with all its qualities and its pathologies and level of decay.

Figure 5: One of the houses from the “Le Tanche” settlement

Figure 6: The laserscan at work in the “Le Tanche” settlement

The survey campaign takes care of both the town pattern and the interesting rural settlement named “Le Tanche”. Infact here some good samples of rural and original housing can still be found. An articulated campaign of inspections is planned for the towns of Pegli, Tabarka, Nueva Tabarka and Calasetta, where a generous photographic survey was done and a lot of suggestions and impressions were gathered. A selected set of cartography, books, old pictures, various multimedia materials have been collected and composed in an accessible archive to work as common information base for the whole research group. The further project development will see the selection of specific themes, trying to focus on the meaningful common characteristics. To enhance the interpretation of the urban patterns, it is to say that all these towns are “new towns” and they have the specific characteristics of these kinds of settlements.

3.2 Constants: typological studies

The typology used in the first houses built in Carloforte was chosen by the settlers themselves. Today there are hardly any traces of them, although - as you can see in the photographic documentation of the mid XIX Century - we can say that it was the same type that still populates the rural area of the island, the so called "baracca". This is a simple construction, a square of 5 x 6 meters with single internal space. The main façade has a single opening of access to housing, and is topped horizontally at about 3.5 meters in height above the level of access. The interior is a single space, covered by a single pitched roof and split in 2 parts by a small wooden slab forming a loft. Entering from the front door on the street there is at first the kitchen with fire and fireplace on one side, and the steps to access the attic. The remaining space is occupied by the sitting-room, while upstairs the bedroom is located, ventilated by a window on the rear façade. The typology is completed by a cistern located under the terrace outside the entrance, which receives the rainwater collected on the roof through a system of gutters and downspouts. A small "Butron" was placed next to the entrance, evacuating the sewage directly overboard. The walls were built with masonry and floors with stout wood girders: board in the attic, while slats, reeds and tiles are used for the roof. This typology, although particularly suited to the site, is similar to other rural types that can be found in areas of the Mediterranean. However it is interesting to consider its way of aggregation to form villages. Under this glance it could be particularly enlightening to analyze the laws of aggregation of the village "Le Tanche", for it consists in a set of huts clustered along a road.

3.3 Variables: urban system and fortification

Unlike the houses, edified directly by the settlers, the urban plan and the fortification systems -although used by the settlers- were designed by military engineers chosen by the state apparatus.

Figure 7: One of the gates in the Carloforte town centre

This fact induced project choices reflecting, in some precise details, the language style coming from each of the designer origin towns and do not put in evidence the typical tabarkinian character.

4. CONCLUSIONS

The research is actually under development. The gathering data phase is almost completed, so we can say that the overall mosaic of traces shows some ideas useful for the next steps of this study. A very important aspect is the evolution of the settlement: now it appears quite clear how the "typical" rural housing is the first step of all these towns, with a construction of the town starting from a simple group of housing, made to define a continuous façade and to allow an easy subdivision of the properties. Later, with the growing of the population and with the rising of the needs, the original houses started to be reconstructed and replaced by larger and more comfortable and enhanced buildings. To better understand and to present efficiently this urban story there will be soon the development of some versatile three dimensional models, aimed to show correctly the main phases of the towns from the Pegli migration. The state of advancement of the whole work is in itself a good and useful document, while a solid and complete image of a large part of the town is archived with a high level of details in its aspect in June 2010. The following treatments will produce the first accurate documentation about the state of the town since its foundation.

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PHOTOGRAMMETRIC TEXTURE MAPPING OF COMPLEX OBJECTS

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KEY WORDS: Cultural heritage, laser scanner, texture mapping, photogrammetry

ABSTRACT:

Today's continuously growing demand on 3D textured models has given rise to many different methods for the production, maintenance, publication and exploitation of this kind of data. 3D content creation and presentation is currently drawing the interest of all major Information Technology and Research & Development stakeholders given the range of well established and prospective applications on education, entertainment, science, internet, tourism etc. This paper is dedicated to highlighting various aspects of the creation of high quality 3D textured models for various applications, while arguing the advantages of integrating photogrammetric methods in the texture mapping process. Drawing on the authors' experience two example cases of complex objects are presented in order to introduce the reader to the techniques employed, the tools that were developed and the potential of the proposed process.

1. INTRODUCTION

3D modeling is currently one of the most active research areas. The number of applications that already exploit or could prospectively employ 3D content is virtually unlimited. Also, the multiplicity of the acquisition systems, processing software and developer background and skills has resulted in a variety of approaches. Many contributions have been dedicated to reviewing various acquisition systems (Beraldin, 2000) and classifying surface reconstruction and measurement techniques (Remondino, 2006). There are also numerous papers on the subjects of texture blending, stitching, registering or mapping in general. In many of the publications authors present methods that automate or optimize a part of the process and describe the approach followed for various example projects. (Berardini, 2002) vividly illustrates the diversity of the various approaches applied, in offering an excellent review on algorithms that have largely been employed for the various steps of the 3D modeling pipeline.

The main objective of this paper is to advocate the use of photogrammetric procedures for high quality texture mapping of complex objects and sites. Although most 3D acquisition systems enable the user to capture the colour of an object either as a native system option or by the use of special gadgets such as custom arms and frames, the colour of the end product may be poor. Besides colour variations due to different illumination conditions, the images required to fully texture a model usually significantly outnumber the required scans. In most cases if only the images acquired from the scan setups are used, texture on the final model may be stretched at highly curved areas, invalid in parts that were occluded or non existent in object areas that may not be acquired or in areas where the acquisition process may fail. In almost all cases geometric information may easily be processed, healed or even artificially modelled in order to have a closed-surface model. However this is not the case with colour. The photogrammetric registration of images with a 3D data model is a process that effectively disengages the geometry acquisition process from the acquisition of images. In this respect, the geometry of an object may be recovered by use of a relatively limited number of set-ups, whereas hundreds of images may be acquired in order to texture the model with high resolution colour. Of course additional point measurements may be required in the field, but the end product is metric, the overall accuracy is uniform and texture is accurately registered. The research presented here also includes information on how the authors properly adapted and combined various photogrammetric and texture mapping software and processes, in order to handle numerous images per object, eliminate color variations and illumination differences, produce seamless high resolution texture maps and create realistic 3D models that are easy to load over the internet and provide free user interaction. Since this paper mostly employs commercial software an extensive review of the related literature would far exceed the scope of this paper. However, the next paragraph includes a few references in order to provide information on related research, highlight the merits and prove the potential of the methods proposed here. Some examples, are given so that the efficiency of the suggested approach is proved. Finally, some conclusions and future research complete this contribution.

2. RELATED WORK

3D modeling is invariably related to a significant number of research areas including, among others, electronics, optics, mathematics, software development, computer vision, multiple view geometry, computer graphics and photogrammetry. Photogrammetry has for long been a collection of techniques that enable the production of line drawings, orthorectified images, developments and surface reconstruction of objects or landscapes, through combining images and object measurements. Traditional photogrammetric products such as orthophotos, orthophotomosaics and developments are the metric equivalents of orthographic-view renderings, multi-image-based renderings and texture maps respectively. In the recent years, the great evolution of various 3D sensing systems has drawn the interest of photogrammetrists and resulted to a great deal of research activities with the aim to combine 3D acquisition systems with the photogrammetric processes. Currently the use of e.g. laser scanner data for the production of orthophotos and line-drawings is fairly standard. However, the combination of 3D acquisition systems and photogrammetric methods for the production of high resolution 3D textured models still remains a challenge.

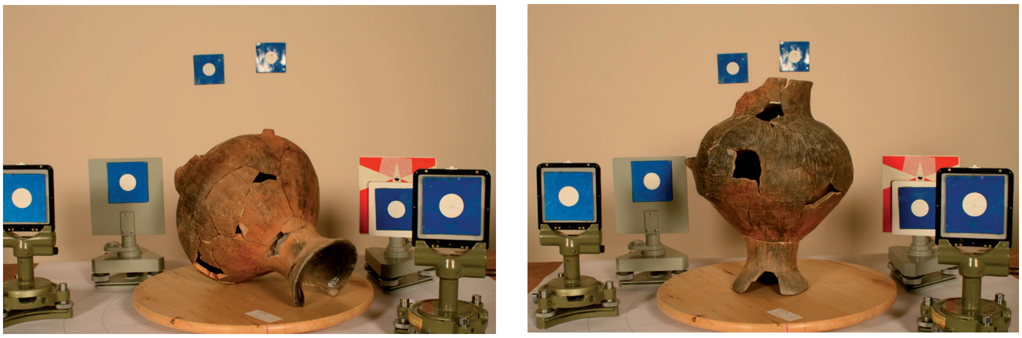

Figure 1: Example of target configuration for different positions of the object

Typically, a 3D modeling workflow can be summarized in three basic steps: 1) surface reconstruction, 2) texture mapping and 3) publication. Over time numerous algorithms for surface reconstruction have been presented, including photogrammetric modeling (Debevec, 1996), shape from silhouette (Niem 1999), structure from motion for uncalibrated image sequences (Pollefeys, 2004), dense correspondence search (Van Gool, 2002) etc. Also, various systems such as laser-, triangulation- and structured-light scanners have been employed for various applications. All of these methods yield low or high density 3D mesh surfaces depending on the resolution of the system employed and the applied algorithms. For this research, data acquired by 3D laser scanners are employed. Also, there are various methods as to how the texture is binded to the 3D surface model. In some cases, such as in (Debevec, 1996) and (Beraldin, 2002) texture is drawn from images that have been registered to the 3D model by a photogrammetric orientation procedure. In other cases, such as in (Pollefeys, 2004) and (Van Gool, 2002) the texture is acquired from the images that were used for the reconstruction of the object surface. Another approach is presented by (Baumberg, 2002) who binds each polygon of a 3D mesh to a single image and processes the seams in all texture images so that no color discontinuities appear. The approach of (Rocchini, 1999) is however one of the most interesting found in related literature as it is one of the few cases where an actual texture map is created from a series of images that are registered onto the object surface with a model much like the collinearity equation used in photogrammetry. Another approach that bears great resemblance to the methods proposed in this paper is that of (Beraldin, 2002), who uses photogrammetrically oriented images to texture the 3D model of a crypt. In that way Beraldin achieves to accurately register detailed images on a high density polygonal model. However the scheme proposed in that paper does not provide a way to correct for reflectance variations and therefore the method would give poor results for highly curved objects or if the original images were acquired for an outdoor application, where the lighting conditions are not controllable. Moreover, since a fairly simple photogrammetric projection algorithm is applied in order to map the 3D coordinates of the mesh vertices onto the original images the problem of occlusions is also not addressed, making the application of the proposed method unsuitable for highly complex objects. In order to address the problem of inconsistent reflectance, the approach proposed in this paper employs a zippering method for fairly simple objects; in case of highly complex objects, a texture map is employed. Furthermore, in an effort to address the problem of occlusions an algorithm has been developed in order to explicitly check for object-camera visibility.

Regarding publication, i.e. the way chosen to present a 3D model there are two dominant alternatives: 1) image based rendering or 2) creation of an actual 3D textured surface model in a suitable format. Image based rendering, is a way to create view specific renderings of an object combining surface and image data. In this respect one may create a few frames that may be combined with a restricted object motion. Therefore, although, this method is suitable for the creation of virtual or augmented reality visualizations while obliterating the need for explicit 3D surface reconstruction, it does not allow for free user interaction. On the contrary, although the creation of an actual 3D textured surface model may be quite elaborate, it certainly enables free user interaction and provides content for high quality photorealistic visualizations. These very requirements i.e. high user interaction and high quality visualization lie at the heart of this research and define all of the steps of the process as presented in this paper. To this end, this paper proposes an approach that employs 3D acquisition systems, photogrammetric algorithms, texture mapping methods and various data formats. The main advantages of the methods presented is that they enable: 1) the accurate, metric and detailed acquisition of an object or a space by employing various scanning systems, 2) the accurate registration of high resolution images throughout the object space by means of photogrammetric methods, 3) the efficient and realistic creation of real-life materials for complex objects through texture mapping and 4) the potential of employing realistic 3D models in visualizations, interactive applications and various platforms by publication in various data formats.

3. PHOTOGRAMMETRIC TEXTURING

This paper demonstrates the proposed methods by use of two examples i.e. a piece of pottery and a rather large and complex monument. In both cases, surface scans were obtained by a laser scanner and high resolution images were acquired by a calibrated digital camera. Also, various targets and points were measured so that photogrammetric orientation of the acquired images would be enabled.

3.1 Texturing small objects

Typically, in order to apply photogrammetric orientations, special targets or points of detail are measured during the data acquisition process from several setups around the object of interest. In this way a local network is established and the coordinates of the nodes and the measured points are calculated in a common reference system. This process allows for the acquisition of numerous point measurements and enables the accurate registration of the digital images onto the object surface. Therefore, these methods are ideal for large objects such as monuments or even entire spaces such as archaeological sites, buildings etc. However, when working with small artefacts of historic value it is absolutely forbidden to attach any kind of targets directly on the object surface and it would be very laborious and inefficient to measure points of detail of the object surface since this would require the acquisition equipment to move several times. Furthermore, even if one decided to actually rotate all of the acquisition equipment around a small object, there would still be aspects such as the bottom or the top that would require moving the object in order to acquire the entire surface. Therefore, an alternative acquisition approach was developed to accommodate data acquisition for small artifacts. Each object was placed on a turntable and several targets were placed at fixed positions around the table (Figure 1). The scanner and the camera were also placed at fixed positions. For each scan the object was placed centrally of the turntable taking care that the targets were not causing occlusions both for the scanner and the camera. For every scan the scanner would acquire the surface of the object at 1mm resolution and a digital image was also acquired. For a given position of the object, scans were obtained by rotating the table 45^o at a time and all of the targets were acquired at the beginning and the end of every cycle. For different objects the positions of the targets, the focus of the camera and the scanner would be properly adjusted. Later, offline, each scan is processed so that points corresponding to noise or to the background are deleted. Each scan was exported in ascii format along with the positions of the acquired targets. The data corresponding to the 45^o scan-cycles were specially processed by a routine developed in Matlab whereby the 8 scans of a cycle along with the positions of the acquired targets were approximately transformed into a common reference system. This was necessary in order to provide a good initialization to the registration algorithms. This data was later imported in the form of point clouds in Geomagic were surface registration was performed. After the registration of the scans, the new transformed positions of the targets were exported so that they could later be used for the photogrammetric registration of the acquired images onto the object surface. Since all scans were registered, the object surfaces were modeled as 3D meshes. The resolution of the 3D meshes was that of a 3-4 mm so that the final model would adequately represent the shape of the object (for medium size objects i.e. 30-60 cm) and the data file would also be small enough for presentation of the textured model through the internet.

In order to texture the 3D model, the photogrammetric software Image Master of Topcon was used in this case. Image master is a program that was originally designed to couple and enhance the functionality of an imaging total station. Nevertheless, this inexpensive software is one of the few photogrammetric programs that allow the user to import a 3D mesh in the form of a DXF or a TIN file and apply textures on the surface based on images that are photogrammetrically oriented. In Image Master one may import a 3D mesh, a series of point measurements and digital images. Each image is associated with a camera that may be calibrated by the calibration module of Image Master or the required values may be given manually for the parameters of a chosen calibration model. In Figure 2 an illustration of the measuring environment of Image Master is presented.

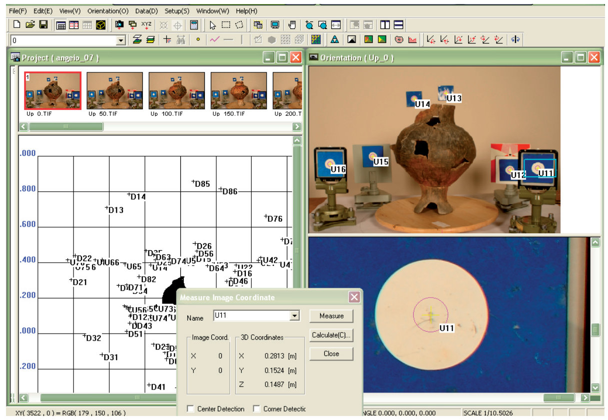

Figure 2: The interactive measurement environment of Topcon's Image Master

The orientation and measurement procedures in this program are rather straightforward. However several drawbacks in the texture mapping process have been identified. For instance, each image is projected onto the object surface and the related texture map is calculated based on the current view of the model probably by employing some kind of orthographic projection scheme. Also, if an image is selected to texture a model, all of the polygons that fall into the image projection cone are associated with the given image. Moreover, although it is possible to employ multiple images in order to texture an image, the results are not satisfactory. Additionally, if an object is large and an image covers only a small part of the surface, the size of the texture map that is created, depends on the size of the entire object and the view chosen at the time the texture mapping command is given. In order to overcome all of these problems, and considering the requirements of the application (i.e. creation of high color quality textured 3D models for web-based user interaction), all of the steps of processing were especially adapted. Specifically, with the aim of creating high resolution texture maps, the 3D mesh surface of the objects was cut into several large pieces. Considering that the texture maps created with Image Master are view dependent and parts of the surface that are imaged poorly for a given view are also textured poorly, the surface was cut so that each piece could be viewed in approximately uniform resolution and without severe deformation from a given point of view. Additionally, the positions of the original images were also taken into account before cutting the object surface. Since each part of the surface would be associated with a single texture map, and in an effort to ensure colour continuity, each piece was selected so that its main colour would be drawn from an image acquired facing the central part of a piece, whereas images acquired from nearby positions would be used as seams for the borders of each piece. Applying this concept, for each piece of the surface, an appropriate view point was selected and all associated images would be used for the creation of texture maps. Each piece was in this way associated with 3 or more texture images depending on the number of its immediate neighbouring surface pieces. The texture images created for each piece were later manually processed and merged into a single texture image through Photoshop (Figure 3).

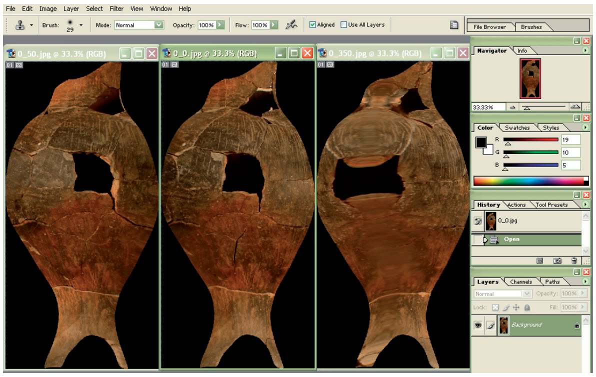

Figure 3: Texture images created for the synthesis of a single texture map for a part of the object surface

The final model was exported in VRML format and the texture images were associated with the respective 3D mesh pieces. This process enabled the creation of 3D models of sufficient geometric detail and high quality color, i.e. uniform and high resolution, high contrast, seamless integration of images, no stretched areas, no false-textured areas and no discontinuities. Also, all of the information was successfully recorded in a relatively small-size file in a very popular free data format that allows for high user interaction through freeware widely available on the internet. An example is given in Figure 4 by means of a snapshot of the final 3D textured model in the Cosmo VRML.

In conclusion, although in this case the 3D surface was acquired by some equipment that was not designed to also provide high quality color with each scan, texturing of the final model was enabled by the integration of photogrammetric techniques in the modelling workflow. Such a solution could be employed for systems that may provide poor or no color. Moreover, this process may employ commercial software, but the problems highlighted here are rather common and the functionalities required to address these problems can also be found in other commercial software or may easily be programmed in a scripting language environment such as Matlab.

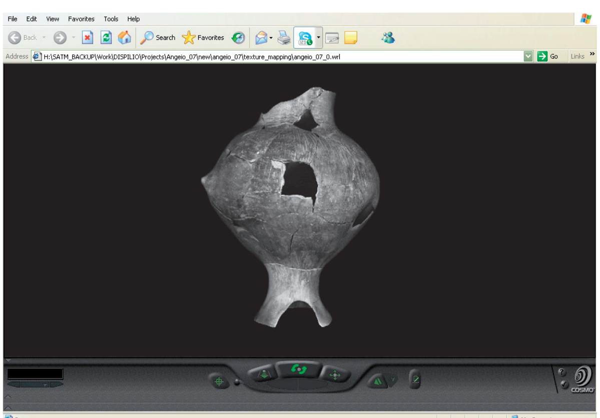

Figure 4: Snapshot of the final textured model in the Cosmo Player VRML plug-in

3.2 Texturing large objects or complex sites

By applying the methods described in the previous section, the authors have achieved to create 3D textured models for a variety of object shapes. However these methods needed to be revised for the case of a large monument such as the Zalongon complex of sculptures. The main reason is that in order to texture a large object and retain a predefined amount of detail (e.g. details of 5mm to be visible) a great number of pictures must be acquired. Also, depending on the complexity of the object to be modelled, it may be required that the model surface is divided into a significant amount of pieces.

The monument of Zalongon is an 18m long and 13m high complex of sculptures designed and built in the 50s by George Zongolopoulos. The related project involved the geometric documentation and 3D modeling of the monument in order to guide the restoration process and create media for presentation and dissemination purposes. With regard to the restoration procedure, several specially adapted processes were designed and applied, including: the production of the required line-drawings, orthophotos, leveling information for the foundation of the scaffolding that would be used, detailed photogrammetric surface acquisition for the destroyed upper parts of the two taller forms, CAD surface representation and reconstruction, data production for the creation of a scaled model, scanning and registration of scaled prototypes for the destroyed parts and various area and volume calculations in order to accurately estimate the amounts and the cost of the materials and the special conservation actions of the restoration process. Although these processes are very interesting in their own right a more detailed description would far exceed the scope of this paper and therefore the reader could refer to (Valanis, 2009) for more information. Here, the focus remains on the processes employed in order to create the 3D textured model of the monument. In this case high quality color and free user interaction were required also.

Scanning the monument involved a total of 16 scans that were registered through a specially designed process (Valanis, 2008). The meshing operations resulted to a 3D model of approximately 700K polygons, since a resolution of 3cm was dictated by the project requirements. Also, a total of 239 images were acquired at two stages, i.e. originally images were acquired from the ground and at a later stage, when the scaffolding was set, another set of images were acquired for the upper parts of the monument. All images were acquired by calibrated cameras and with use of appropriate lenses, chosen according to the acquisition distance so as to ensure that the desired amount of detail would be captured in all images. Here it must be noted that for all photogrammetric products, a scale of 1:20 was designated, i.e. details of 5mm (human eye resolution multiplied by the scale factor, in this case: 0.25mm x 20 = 5mm) should be visible throughout the object surface. Also, during field measurements, a total of 327 control points were acquired.

For any application of photogrammetric documentation, a significant amount of data is always acquired. The total amount of images and control points is always a function of the object complexity and the desired scale of the final products. In the case of the monument of Zalongon both factors favoured the acquisition of hundreds of images and control points. However, although for a typical 3D modelling process these amounts of image data may be intractable, standard photogrammetric processes such as orthophoto production, may easily accommodate even significantly larger data sets (Tsingas et al., 2008). In this respect, and in order to accurately texture the 3D surface of the model all of the acquired images were photogrammetrically oriented. The photogrammetric processing that was carried out mainly through the Image Master software where all of the images were imported, control points were measured wherever visible, tie points were also measured and all of the measurements were processed in bundle adjustments.

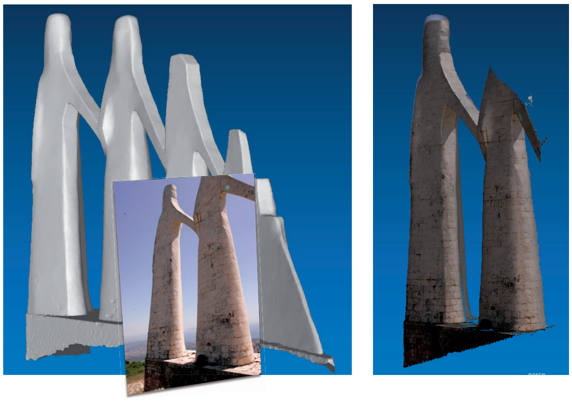

Figure 5: Example of the input and output of the photogrammetric texture mapping module created in Matlab

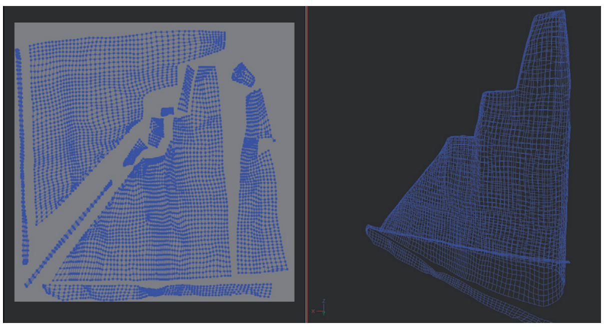

Figure 6: Part of the constrained mesh created for the monument of Zalongon as illustrated through the UV mapping software

Figure 7: Texture maps created for the main body of the Zalongon complex of sculptures. Each map is 4K x 4K

The processing described in the above resulted to the calculation of the orientation parameters of all of the acquired images. This data was later on used so as to accurately register the images with the 3D object surface. Out of the 239 images that were acquired, a subset of approximately 100 images was selected for the texturing process. All of these images were processed with a script that was created in Matlab in order to project each image on the mesh surface and associate 3D nodes with the corresponding texture coordinates. The model used for this purpose was the collinearity equation including the appropriate correction parameters for radial and tangential lens distortion. The algorithm based on the orientation of each image defines the image bundle and excludes all areas that fall outside the bundle. Also, depending on the relative orientation of the principal axis camera vector and the normal vector of a surface triangle, all backfacing triangles are rejected based on an evaluation of the angle formed between the two vectors in each case. Finally, the algorithm checks for occlusions by projecting all of the remaining triangles onto the image plane and rejects nodes that fall within other triangles based on a comparison of the node-camera and triangle – camera distance. This algorithm given a series of images and a 3D model results to a set of .obj files such that each image functions as a texture map for the corresponding part of the surface. An illustration of the processing and the outcome of the Matlab module is given in Figure 5.

Obviously there is significant overlap between the acquired images and the respective .obj files and there are significant intensity variations even for sequentially acquired images. Therefore, in order to effectively integrate all of this information and facilitate texturing the model, a texture map is required. For a given 3D mesh, commercial software solutions exist in order to create a basic UVW texture map and associate 3D coordinates with a 2D customized texture image. Such tools enable the development of a 3D surface either in its entirety, in case of a simple object, or in parts, whenever the object of interest is rather complex. Another significant aspect of this process is the density of the mesh to be used. A mesh comprising of 700K tiny triangles, such as the one in this case, would be almost impossible to process. This is mainly because the editing of the 3D to 2D data grouping and mapping is done manually. Also, the form of the model in question is highly complex as the surface is highly curved and comprises 3 handles. The quality of a texture map and, consequently, of the final 3D model, depends heavily on the form of the 3D surface, the parts that are grouped and developed in the 2D space, the relative size of surface units, the selected resolution, the quality of the original data etc. In this case, it was desired that the final model would be small enough so as to enable easy internet access and a high degree of interaction, but the texture colour should be as accurate as possible. In this respect, it was selected, instead of working with the full 700K 3D surface mesh to construct and work on a significantly lighter constrained mesh. A constrained mesh is a collection of quads that is usually manually designed onto a 3D mesh using GSI of Geometric Systems Inc. It resembles the contour layout of a NURBS surface, but the difference is that all quads are planar. In this respect a constrained mesh was designed for the monument of Zalongon. The constrained mesh was broken into 5 pieces and processed in DeepUV, a low cost UV mapping software. In Figure 6 a part of the constrained mesh is illustrated through the UV mapping software.

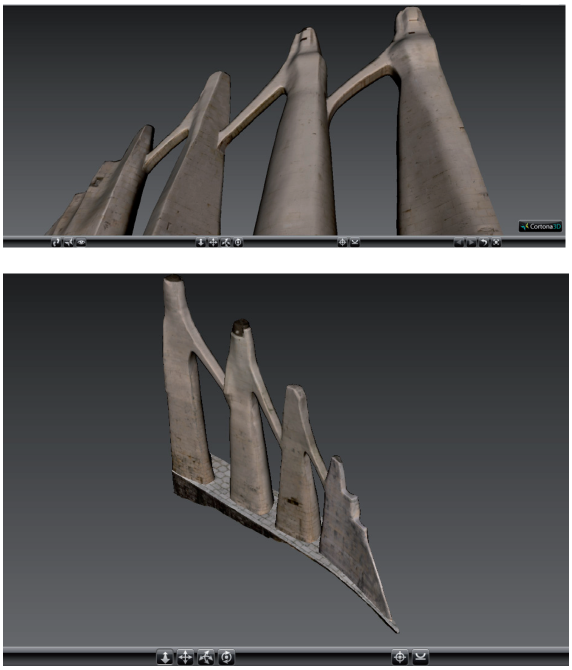

Figure 8: Views of the 3D textured model of the Zalongon monument through the Cortona 3D viewer

By breaking the constrained mesh into 5 pieces (4 pieces for the 4 figures and 1 piece for the floor) it was possible to efficiently achieve the even distribution of the nodes on the UV level, ensure almost uniform scale and go for higher resolution as each piece was associated with a 4K texture map. Based on these UV mappings, the color of the individual .objs was projected onto the related texture maps. This resulted to a series of texture maps that later on were combined into a single texture map for each piece. During this step, care was taken so that adjacent parts were textured from the same images so that no seams are visible and for each texture image all parts were properly adjusted and corrected for tone, brightness and contrast differences. The final 4 texture maps that were created for the monument are presented in Figure 7.

By exporting the 3D model in a VRML format and the associated texture maps in JPEG format, the total file size is no more than 10MB and by installing a free plugin such as the Cortona 3D viewer in an internet browser, any user can easily interact with the model. The tree dimensional model of Zalongon combines unique texture quality and high user interaction. The user can freely handle the model in space and view the model from every imaginable aspect. In Figure 8 two snapshots of the model in the Corton viewer are illustrated. In the first image the viewpoint is selected as if the user is actually standing in front of the monument. The second image is captured form an elevated point rendering a view that would be impossible for the actual visitor.

In Figure 9, an example of the actual resolution of the 3D textured model is given. By employing the same methods and by modifying parts of the process, the authors actually created two 3D textured models for the Zalongon monument. The first illustrated the original status of the monument, while the second model was created so as to present the current form of the monument, i.e. after all of the restoration work has been completed. The two models are available for display on the internet and a small HD movie has been produced by the authors for dissemination purposes. To this end an environment that resembles the actual surroundings of the monument has been created virtually, including the anaglyph of the greater area and the sky was simulated, given the orientation of the monument and its geographical position. The movie presents the monument in full texture, beginning with the original state and later on transforming to the new, restored form. In Figure 10, 4 scenes created for the movie sequence are presented.

Although quite laborious and complicated, the process described in the above resulted to the creation of texture maps that are unique for their high resolution and accuracy given the size of the object. The selected format and 3Dviewer allow for the completely free, unconstrained user interaction, enabling customized selection of the point of view, walk-through, flying mode and free zoom in for full resolution display.

Figure 9: Detail of the final 3D textured model captured through the Cortona 3D viewer in order to give an example for the quality and resolution of the textured maps created by the proposed methods

Figure 10: Scenes of the image sequence created for the production of an HD movie for the dissemination of the monument

4. CONCLUSIONS

The examples presented in this paper prove the potential of photogrammetric texture mapping. The integration of photogrammetric processes into the 3D model texture mapping workflow introduces several benefits such as: accurate image to 3D surface registration when the original color is poor or non-existent, uniform and generally higher resolutions, exploitation of a significantly larger amount of image data and elimination of poorly textured model areas. It may be argued that existing methods could yield similar results but in most cases it remains a challenge to work with large objects and sites at high resolutions. In this area, photogrammetry can be the key for highly interactive and real-life textured models. The output of the process is unique regarding the quality of the final texture maps but also light enough for exploitation in various applications such as: movies, games, Google-earth applications, 3D GIS etc. For all of the above mentioned applications, light weight models with rich realistic texture would be valuable assets that could increase their appeal, potentially draw new users and inspire new functionalities. Regarding future work, the authors will be working on optimizing the photogrammetric texturing module so as to include texture blending and further automate various parts of the process.

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GEOMETRIC DOCUMENTATION OF THE ALMOINA DOOR OF THE CATHEDRAL OF VALENCIA

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KEY WORDS: Cultural Heritage, Documentation, Terrestrial laser scanner, 3D Modeling, Texture

ABSTRACT:

Photo-realistic 3D modeling is a process that during the recent years is gaining ground in monument documentation, visualization and dissemination. The combination of a variety of data acquisition technologies, with photogrammetric processing and computer graphic methods has certainly been fruitful. Low-resolution 3D models are frequently used for information dissemination about monuments, e.g., via web-pages in the form of a VRML model. However, the creation, publication and interaction with high resolution photo-realistic 3D models are still rather challenging and require cumbersome tasks. It is certain that a high-quality photo-realistic 3D model, produced to guarantee a given level of accuracy, is a valuable tool for applications involving restoration, preservation and monitoring of monuments. This paper describes the various steps carried out to geometrically document a highly detailed object, the Romanesque door of the Cathedral of Valencia, by a terrestrial laser scanner. The fieldwork and processing stages are described in detail, with special emphasis on the practical difficulties. The final result, the 3D rendered model, is evaluated for its quality and usefulness.

1. INTRODUCTION

It is obvious, that the thorough study of monuments is an obligation of our era. During the recent years archaeological excavations became common practice. Especially over the very recent decades, international bodies and related agencies have passed resolutions concerning the obligation for protection, conservation and restoration of monuments.

The geometric documentation records the present of monuments, as they have been shaped in the course of time. The geometric documentation provides the necessary background for the studies of the past, as well as the plans for the future. Therefore, it may be defined as the action of acquiring, processing, presenting and recording the necessary data for the determination of the position and the actual existing form, shape and size of a monument in the three dimensional space at a particular moment in time. The value of international documentation is presented in The Athens Charter (ICOMOS, 1931).

The geometric recording of a monument is only one, but essential part of the general documentation process dealing with cultural heritage. After the acquisition and development steps, the results are a series of products, usually at large scales, which fully document the geometrical properties of the monument in 2D and in 3D (Georgopoulos et al, 2005).

Due to the spectacular technological advances, especially in the very last years, the collection of the required metric data for a full documentation of a monument is simplified. Furthermore, the development of the computer vision field enables the 3D visualizations of the monuments in a virtual world (Georgopoulos and Ioannides, 2005).

Terrestrial laser scanning allows the quick acquisition of dense point clouds. After processing a 3D model can be produced as well. These results combined with photogrammetric procedures, such as the production of orthophotos, cross-sections, top and elevation plans, represent the complexity of the monuments in standard metric documents.

The aim of this specific study is the full geometric documentation of a small part of a historic monument, the Almoina Door (Fig. 1) of the Cathedral of Valencia (Catedral de Valencia, 2007). For that purpose, contemporary photogrammetric tools based on terrestrial laser scanning and single images are combined to yield highly detailed photo-realistic models.

a)

b)

Figure 1: The Almoina door: a) Front view, b) Detail of the capitals

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The Almoina Door (Fig. 1) is one of the three entrances to the Cathedral of Valencia, each one representing different styles, Romanesque, Gothic and Baroque. The magnificent Romanesque door is located on the southeastern side of the church and faces towards the Almoina Square. It has been historically dated to the 13^{th} century A.D. and consists of a combination of arches and pillars. On the capitals, images from the Bible, Genesis, and Exodus are portrayed. On the arches, there are sculptures of saints and angels, but beasts and monsters are contrastingly portrayed as well. Moreover, fourteen male and female sculptured heads of the first inhabitants are placed above the arches. Over the door, in the upper side of the wall, there is a high window, with pillars on the left and right side, on top of which three arches are formed. The total size of the area of study reaches 17 m in width and 19 m in height.

2. METHODOLOGY

2.1 Equipment

The scanning of the monument was accomplished by using the terrestrial laser scanner *Leica ScanStation 2* (Leica, 2007, Fig. 2). It is a pulse-based time of flight scanner with a maximum range of 300 m. Its nominal accuracy is 6 mm at 50 m and can record up to 50,000 points/sec. The field of view of the scanner is 360° x 270°. It includes a digital video camera of low resolution. Its physical dimensions are 265 mm x 370 mm x 510 mm and it weighs 18.50 kg. It comes with the proprietary software *Cyclone* for processing.

Figure 2: HDS ScanStation 2 during the data acquisition

2.2 Field Work

In order to enable indirect target-to-target registration (Lerma et al, 2008), five Leica HDS retroreflective targets were placed around the perimeter of the object.
The targets were measured with a Topcon 7003i total station from one position. Furthermore, around 60 detailed points were also measured geodetically in order to control the quality of the photogrammetric processing. In addition to the laser scanning, some general stereo-pairs and details were taken with a CANON 1Ds Mark III with a 50 mm Sigma lens. Moreover, some general and detailed pictures were also taken by the CANON PowerShot G11 (3648x2736 pixels) in order to fully texture the 3D model. Both cameras have the ability to give raw as well as jpeg files. The total size of the photo files reached 7,5 GB.
The scanning of the object was performed from five different scanning positions (Fig. 3), measuring 3 to 5 HDS targets from each position (Kraus, 2004). The average point cloud overlap was about 40%. The dual-axes compensator of the laser scanner was always on.

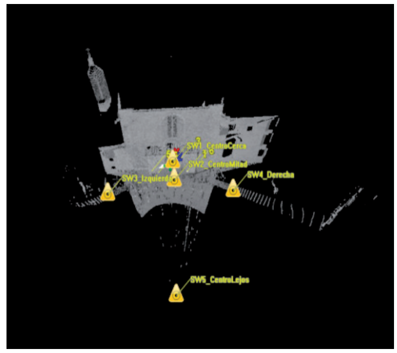


Figure 3: The scanning positions

The distance of the object to the scanner for each scanning clearly differs. However, an equal scanning resolution of 5 mm was set. The field work lasted a total of 8 hours, in which 6.500.000 points were acquired, many of which were obviously retrieved outside the object of interest. The size of the scanning files (imp files) reached 500 MB.

2.3 Processing

2.3.1 Registration of the point cloud: The registration of the five point clouds was accomplished with the *Cyclone* software. First, the point clouds were registered to the HDS targets and later georeferenced (with the help of the total station measured targets) to the local reference system. This was considered the most suitable method of registration in order to minimize the errors. One of the five targets was not distinguished adequately in all of the scans and consequently affected negatively the least squares solution. For this reason it was excluded from the solution. After careful registration, the error reached 0.003 m. The points that were outside of the object of interest were also removed.

2.3.2 Modeling: Modeling serves to create a three dimensional model of the object. This process was accomplished through the software package *3DReshaper* (Technodigit, 2009a). Firstly, the data sets which were provided from *Cyclone* (point clouds) were imported into *3DReshaper*. The extraction of data in the pts format has the benefit of placing each scan in a different layer so that the data can be managed more easily. Eight different point clouds were retrieved, consisting of about 5.550.000 points.
The creation of the 3D model follows 4 stages: firstly, filtering the point clouds, secondly, creating the surface; thirdly, smoothing the surface, and finally, cleaning the surface and hole filling.

Stage 1: Filtering the point clouds
Filtering of all the point clouds was applied first, discarding points creating "noise". Points above a distance threshold were removed. After the filtering processing about 5.440.000 points were left, i.e. 2% of the points were removed.
Stage 2: Creating the surface
The software provides the ability of automatic surface meshing (in Triangulated Irregular Network format) from point clouds in a relatively small time frame. However, it was preferable to create many smaller surfaces. In this way a better representation of details and easier data handling was achieved. The software also gives the option to create meshes while simultaneously removing the noise. It also enables the user to form meshes without removing noise. In this case it was preferable to create the meshes using all the points, since the noisy points were

removed earlier with the filtering command. As a result, through the combination of the layers of the point clouds which were introduced at the beginning, around 90 new layers were formed by separating and merging them (Fig. 4). Some of the layers contained just a small number of points.

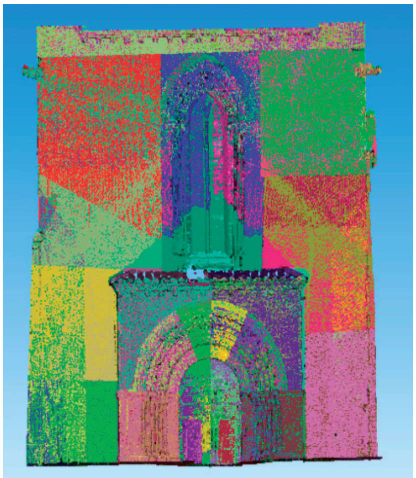


Figure 4: Coloured point clouds after registration

The meshes were formed in TIN format from the software's automatic command, combining all the point clouds which displayed the same part of the object. Through this process 18 meshes were created, with around 10.500.000 triangles formed.
In the smooth areas of the object such as the parts of the stone wall, the results satisfied the demands for accuracy. It represented with great level of detail the shapes and alterations of the object. On the contrary, in the areas with relief such as the areas with many details (arches, pillars, heads, etc.), the created mesh contains much more noise, as well as incorrect triangles, gaps, etc (Fig. 5).
The area just above the vertical axis of the scanner is a special case since the created mesh contains many circular gaps.
On the wooden part of the door (entrance to the Cathedral) a large amount of noise was noticed, which was possibly due to the absorption of the laser beam onto the dark wooden surface.

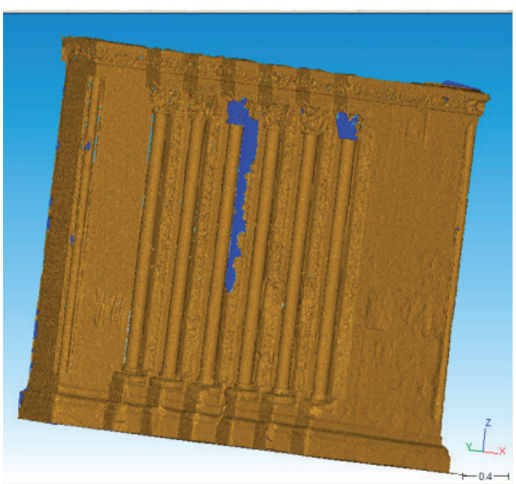


Figure 5: Mesh with lots of sharp edges

Stage 3: Smoothing the surface
Smoothing followed the generation of the meshes since they contained many sharp edges, and wrong triangles (because of the noise). It was conducted carefully in order to avoid erasing of important details for the documentation. The surface smoothing is a very useful function in *3DReshaper*, which modifies the triangle organization so that they "follow" the mesh curves. Generally, the main issue is to find the best compromise between noise measurement elimination and preservation of the maximum of details (Technodigit, 2009b). After some trials, the proper combination of parameters was found (Fig. 6).

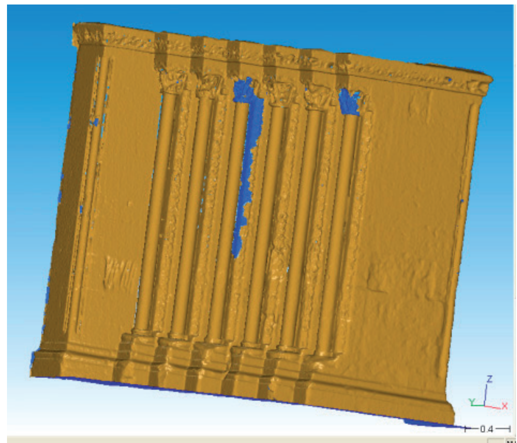


Figure 6: Smoothed mesh

Stage 4: Cleaning the surface and hole filling
The results after the smoothing were satisfactory but there were still some triangles which were clearly incorrect, since they did not belong to the mesh. These areas were noted especially where the object becomes complex. These triangles were removed manually, by a cleaning command. Also, there were many gaps due to the position of certain points (very high and with acute angles). In these areas it was impossible to extract information. The process of covering the gaps was carried out either automatically, with a special command of the program which creates an amount of triangles in any gap indicated by the user, or manually where the automatic command did not yield satisfactory result. In areas where the gaps are too big, bridges were created between the points in order to decrease the size of each gap and later implement automatic filling. At this stage another smoothing command was also locally used to correct the areas with irregular triangles (Fig. 7).

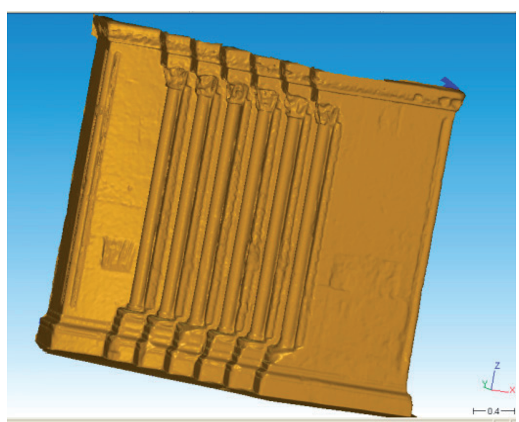
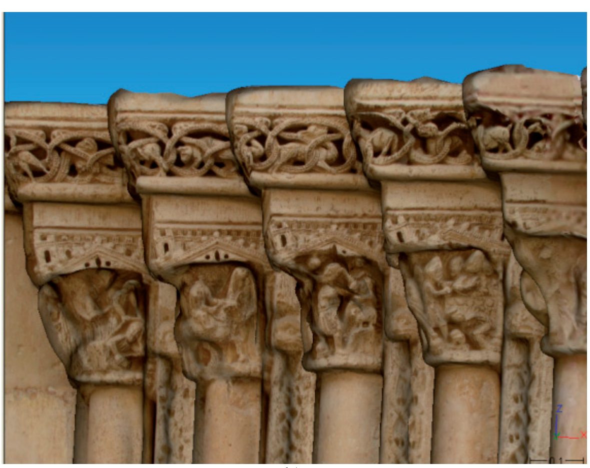


Figure 7: Mesh after cleaning and hole filling

Next, all the meshes were united as one, filling in certain gaps which possibly were formed among them. Simultaneously, the mesh was reduced to decrease the volume of the mesh files to make the data more manageable.

2.3.3 Texturing: The last stage of processing consisted of texturing. This process was also accomplished with the software package *3DReshaper*. The software gives the choice of texture mapping, in which an image is introduced onto the object (preferably not of very high resolution due to the data volume). After the user has measured at least 3 conjugate points between the model and the image, a perspective transformation is automatically estimated and the image is adjusted onto the model (Fig. 8). The parameters of interior and exterior orientation can be introduced if they are known. They can also be estimated if at least 6 conjugate points are measured.
This processing is simple and easy, despite the fact that photos on which the interpolation is applied should be chosen very carefully. In most of the cases, especially in the regions with many details, texturing required more than one photo due to the lack of information on occluded areas. So, two or more photos from different perspectives were used.

a)



b)

Figure 8: a) Mesh after texturing, b) Close-up view of the capitals

It was also necessary to adjust the radiometric values and the color of the photos, because they were taken in different lighting conditions. For this procedure, *Adobe Photoshop CS5 Software was used.* The photos used were in jpeg format (smaller files, easily handled).
The filtered (cleaned) point cloud files can be exported in ascii or binary formats such as rsh type (the software's own format), stl, mdl, obj, vrml, etc.

3. CONCLUSION

The use of the described contemporary methodology gives satisfactory products, despite the fact that the terrestrial laser scanner used was a priori not the most appropriate for the fine details existing e.g. in the arches and capitals. On the other hand, the exhaustive metric documentation that might have required the data acquisition with two laser scanners, one triangulation-based for short ranges and one pulse-based used for mid-range distances, has been overcome with efficient meshing in 3D and the textures coming from the images.
The problems that the users should cope with are mainly referred to the large data amount which has to be handled by the computer and the applied software. These kinds of projects require powerful computers with fast processors and graphic cards. Indicatively, it is referred that for the mesh creation from a point cloud with 450,000 points approximately, 2-3 minutes was required and for smoothing, about 5-6 minutes with a 3.4GHz Pentium D processor. But the most lengthy process was the mesh cleaning and the hole filling. This task was done manually, due to the inability at present to perform by automatic means (with enough reliability) the afore-mentioned tasks. In fact, 3 to 10 hours approximately were needed for each mesh, depending on the complexity of the surface.
Clearly, the geometrical documentation should not include only the formation of the 3D model. The conventional photogrammetric procedures are still irreplaceable and necessary. It is important to emphasize the need of using photogrammetric approaches to capture data, provide control and ensure geometrically correct models (Tsakiri et al. 2003). For the full geometric documentation of the monument, orthophoto mosaics are still required to display the actual conservation state of the monument.

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ADAPTIVE LIDAR SCANNING OF HISTORIC BUILDINGS SUPPORTED BY AUGMENTED REALITY USER INTERFACES

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KEY WORDS: 3D Modelling, Augmented Reality, LIDAR, Visualization, User Interaction

ABSTRACT:

3D models of buildings and spatial environments are rapidly becoming a standard tool in the documentation, management and presentation of architectural, archaeological and landscape cultural heritage. Despite advances in acquisition technologies like photogrammetry and LIDAR scanning, the costs for data collection are still a significant and often limiting factor, especially for large scale models. In the research project reported here we develop and evaluate techniques for the acquisition of large models driven by relevance, using an adaptive scanning approach that adjusts the resolution in which a model is acquired to its relevance. New processing techniques and a user-interface that integrates a fast augmented reality visualization of the current model state with quality and resolution metrics computed on the fly enable operators to interactively control the acquisition process and conduct quality control on-site.

1. INTRODUCTION

Despite technological advances the cost of creating and maintaining the 3D models required for the documentation, management and presentation of architectural, archaeological and landscape cultural heritage remains a challenging issue.

One central problem in applications using 3D models is the trade-off between detail and acquisition cost (during acquisition) as well as processing speed (during use). Much detail (even on a small scale) requires the complete scan to be conducted at high resolution and leads to long acquisition time, large amounts of data, and complex processing. Rapid scanning - in contrast - will be faster but only provides lower resolution and an overall coarse model.

In our approach we explore an alternative way to provide 3D information on a large scale, applying the concept of generalization - in the cartographic sense of meaningful abstraction - to 3D data derived from LIDAR scans, starting at the acquisition phase. In many use-cases a high-amount of detail is only required for those objects that are of high relevance to the user while others are only relevant as context. E.g. in a model of historic architecture a highly precise model of the building surface may be desirable but the same amount of detail is neither required nor desired for the leaves of plants in the environment.

An effective user interface is required to control the acquisition process to enable this selective acquisition of large-scale geospatial models where the amount of detail varies and is driven by relevance. An augmented reality (AR) user interface that overlays the current 3D model on a view of the real world environment provides an intuitive way to check the current state of the acquisition process. By simple touch interaction in the AR presentation operators can select objects of special interest and adjust the acquisition resolution on the fly. In addition quality metrics can be calculated and displayed on the model to enable quantitative checking of the acquired data on site.

The implementation of such a system in turn requires fast and reliable matching and processing techniques that operate at high speeds and can be used in the field.

As part of the ongoing research project it is planned to add facilities for semantic modelling and to address relevance driven presentation / visualization aspects at a later stage.

2. RELATED WORK

A growing number of applications and domains make use of laser-scanning technology as a means for modeling 3D cultural heritage (Barber et al., 2005; Stenberg, 2006; Visintini et al., 2006), and architectural modeling (Levoy et al., 2000; Akca et al., 2006). Laser scanning based documentation benefits from a very detailed depiction of complex objects that could not have been documented otherwise, and from a millimeter level of accuracy, which enables an accurate reconstruction. Nonetheless, the surveying process and later on the intensive geometric modelling incurs high costs that make such documentation expensive, and thus impractical in many cases.

In order to improve terrestrial laser scanning processing, research into autonomous and computationally efficient procedures has seen growing interest in recent year. The focus was mainly on autonomous registration of scans and on geometric primitive extraction. Registration of individual laser scans, aerial and terrestrial, into a common reference frame is a fundamental step in aligning all data into a common reference frame, thereby forming a seamless dataset. For terrestrial laser scans, commercial registration software does not provide a complete autonomous solution unless some specially constructed (and usually expensive) targets are deployed in the scanned area. Focusing on pairwise registration of terrestrial scans, a keypoint registration scheme has been developed and supplemented later on by the RGB image content (Barnea and Filin, 2007; 2008). Later on, inclusion of intensity data has show significant improvement in accuracy and efficiency. In reference to object modelling and identification, the challenges to be addressed include object shape complexity as well as variations in depth within the scene (typical scans will cover hundreds of meter) and consequently in scale and resolution,

even within a single scan. Zeibak and Filin (2007; 9), Barnea et al. (2007) and Gorte (2007) propose processing of range panoramas, reflection of the acquisition process, instead of processing of the actual 3-D point cloud. As the authors show, effective means to isolate objects, segment the data, compare scans, and recognize objects by non-parametric models are made possible this way.
The software currently used in the 3D data acquisition and modelling process is designed for operation in in-door office environments. A promising approach to improve the usability on-site is the use of the user interface concepts of mixed and augmented reality (Milgram et al. 1994, Azuma, 1997) that integrate the real environment into the user interface. Early work in this direction includes the AR outdoor modelling application by Piekarski and Thomas (2001). New hardware like smartphones makes mobile AR applications for outdoor use increasingly viable and the development of specialized devices like the GeoScope AR input/output device (Paelke and Brenner, 2007) allows to address problems in positioning and displaying for outdoor use-cases like data acquisition where high mobility is not required.

To refine the areas of interest we employ on-site modelling using terrestrial laser scanning: The user interface is based on the paradigm of augmented reality (AR). In the visualization of the modelling interface information on the model (geometry, resolution and quality) is overlaid on a view of the real environment to be acquired. This spatially registered overlay of the 3D computer graphics rendering of the model allows controlling the acquisition and modelling process in a very intuitive way. The operator can directly see the current state of the model, has a straight-forward reference to the real environment and can therefore easily decide and select features for further detailing.
To make this information available on-site a rapid processing of the data is necessary to ensure that the information presented to the user incorporates all information acquired so far. We therefore develop a number of 3D geometry analysis and integration algorithms that match and integrate data from different scans and data sources and provide measures of model quality.
The resulting model can be further refined or extended with additional (e.g. non geometric) information either on-site or back in the office using conventional modelling tools.

3. WORKFLOW AND SYSTEM STRUCTURE

The objective of our approach is the effective creation of 3D geospatial models required for the documentation, management and presentation of areas and buildings based on integrating global data (airborne laser or alternative sources) with local detail acquired using terrestrial laser scans.
The central idea is to control and limit the amount of detail in all processing stages to what is actually required while providing immediate feedback and on-site interaction capabilities. This reduces acquisition time. Modelling time can also be reduced in many cases because modelling problems can be resolved immediately with the original surfaces as the reference. An additional benefit is the reduction in the storage and computation requirements when using the resulting models.
Figure 1 shows the demand-driven workflow into which the acquisition, analysis, integration and presentation activities are embedded.

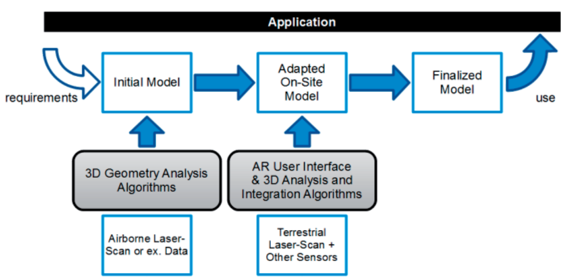

Figure 1: Acquisition and analysis workflow

In many cultural heritage applications initial information on the spatial context of the object/area of interest is already available in different forms, e.g. 2D map data or digital terrain models.
For the purpose of modelling we start with this (integrated) information as an initial model. It can be used to support user orientation during the acquisition process and serves as the spatial context in later use. Within this initial model areas of interest can be indentified in which more detailed models are required. Alternatively, an initial 3D model can be acquired by a cost effective method, e.g. through airborne laser scanning and photogrammetry.

4. COMPONENTS

4.1 Sensors and Data

Laser scanning technology makes direct acquisition of 3D data feasible, enabling coverage of wide regions constantly generating in recent years decimeter level point densities and sub-centimeter level of accuracy. Thus it provides a detailed object description in its actual 3D sense. Accompanying the range data are cameras that acquire high-resolution and texture rich content of objects, enabling to provide nearly photorealistic depiction of the studied scene with little processing. For the tests we use a Riegl LMS Z360I Scanner in combination with a Nikon SLR for texture capturing (Figure 2).

Figure 2: Nikon SLR camera and Riegl LMS Z360I scanner assembly

4.2 Data Processing

The scanner and mounted camera, feature two reference frames which are co-aligned by a boresight transformation. The camera-scanner boresight relation can be encapsulated by a 3×4 projection matrix **P** which represents the relation between an object space point and an image point:

$$x = \mathbf{KR}\left(\mathbf{I} \mid -t\right) X \tag{1}$$

where $X=[x\ y\ z\ 1]^T$ and $x=[u\ v\ 1]^T$, are object- and image-space points, respectively, in homogeneous representation; **K** the

calibration matrix, **I** the identity matrix, and **R** and *t*, the rotation matrix and translation vector, respectively. Radial and decentering lens distortions are calibrated and corrected for.
For each scan, *n* images are acquired at predefined "stops" (every 360/*n* degrees). Assuming that, *i*) the camera is rigidly mounted to the scanner, *ii*) the intrinsic camera parameter are fixed and calibrated in advance, and *iii*) the acquisition position (of the "stop") is fixed across all scanning positions, enable using the same projection matrices for all images of the same "stop" within different scans.
The scanned data (ranging and intensity), is represented in polar coordinates

$$(\rho\cos\varphi\cos\theta, \rho\cos\varphi\sin\theta, \rho\sin\varphi)^T = (x, y, z)^T \qquad (2)$$

with φ and θ latitudinal and longitudinal coordinates of the firing direction and ρ the measured range (Figure 3). Polar coordinates offer lossless raster data representation as the angular spacing is fixed. Range and intensity values set pixels content.

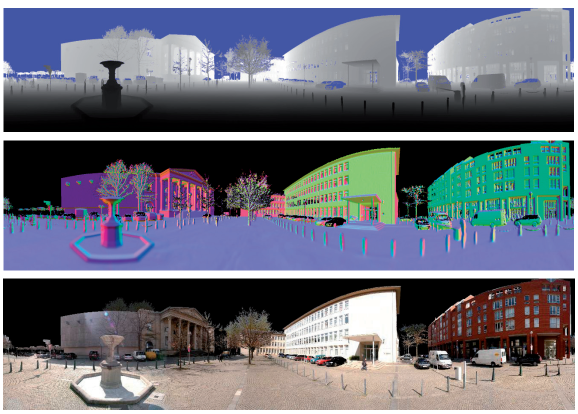

Figure 3: Polar representation of the segmentation channels. The horizontal and vertical axes of the images represent the values of φ, θ respectively. (top) distances as intensity values ρ (bright=far), with "no-return" pixels in blue, (middle) surface normals, (bottom) color (see text).

For data segmentation, we use the mean-shift segmentation (Comaniciu and Meer, 2002), a scheme that was chosen due to its successful results with complex and cluttered images.
As a non-parametric segmentation model, it requires neither model parameters nor domain knowledge as inputs. The algorithm is controlled by only two dominant parameters: the sizes of spatial and the range dimensions of the kernel. The first affects the spatial neighborhood while the latter affects the permissible variability within the neighborhood. These two parameters are physical in a sense. The mean shift segmentation is applied on the: range data in its panoramic forms, surface normals data which are computed from the range panoramas, and color content, which is derived from the acquired set of images. The range channel enables highlighting vertically dominant objects, like tree stems or poles, while the normal based segmentation reveals the ground, façades and other surface objects that appear as complete segments. Color content enables isolating objects which are consistent in their hue.
The integration scheme originates from the realization that the different channels exhibit different properties of the data. Consequently, they provide "good" segments in some parts of the data and "noisy" ones in other parts. Therefore each channel is segmented independently and then a segmentation that integrates them is constructed by selecting the better segments from each channel. In this scheme the addition of other channels can be accommodated without many modifications. The objective is to obtain segments that are uniform in their measured property, where optimally, all data units belonging to the segment will have similar attributes. Additionally, we aim for segments that are spatially significant and meaningful. As such, we wish to assemble large group of data units, preferably of significant size in object space. These segments should not lead however to under-segmentation. In order to meet the need for significant grouping in object space, we set the score of a segment with respect to its 3D coverage. The proposed model is applied as follows. First, the largest segment is selected from all channels, if the segment quality is satisfactory it is inserted into the integrated segmentation. All pixels relating to this segment are then subtracted from all channels and the isolated regions in the other channels are then regrouped and their attribute value is computed. Following, is the extraction of the next largest segment and the repetition of the process until reaching a segment whose size is smaller than a prescribed value and/or preset number of iterations. We note that due to the non-parametric nature of the mean-shift segmentation, re-segmenting the data between iterations has little effect. Figure 4 shows the segmentation results for the scene in Figure 3.

Figure 4: Results of the segmentation

4.3 AR UI

For the implementation of the user interface for on-site interaction we address two device types.
The first category is smartphones using the android operating systems. They provide coarse localization and orientation through the integrated GPS and digital compass. The user interface of our application is realized as video-see-through augmented reality, using the video-stream provided by the camera on the back of the phone and augmenting it with computer graphics of the model and additional information.
Smartphones are highly mobile and relatively inexpensive – within the acquisition system they are best used to interactively mark areas of specific interest and for initial quality control (coverage checking) of acquired data. E.g. (multiple) domain experts on a cultural heritage site can use smartphones to mark areas in the initial coarse model that must be acquired in higher resolution and later check that the acquired data covers all intended areas. We currently use HTC Hero and HTC Desire smartphones with the Android operating system (HTC, 2010).

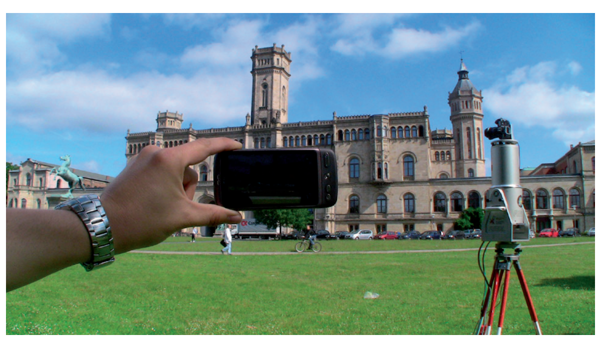

Figure 5: AR UI setup using HTC Desire

Unfortunately, the resolution and accuracy of the GPS position and compass orientation in smartphones is limited and can be insufficient for detailed modelling. We therefore employ a second device when a higher resolution is required. The GeoScope (Paelke and Brenner, 2007) is an augmented reality device that can be installed on a standard geodetic tripod at arbitrary locations. Its main components are a high resolution LCD display with a touch-screen that faces the user and a high resolution camera that is mounted on the back, looking into the environment. Similar to a telescope the GeoScope can be turned in two degrees of freedom (pitch and yaw). The rotation angles are captured with high resolution and precision by mechanical sensors. In combination with the position of the tripod (which can be determined precisely by geodetic means) all position parameters of the GeoScope can be determined with high precision, allowing for spatially correct augmentation of the video images in a similar setup to the smartphones, but with higher resolution and precision. When acquiring data with a laser scanner the same tripod can be used both for the scanner and the GeoScope, simplifying logistics. The precise visual overlay of the acquired model on the real environment can be used for detailed quality checking, refined modelling and semantic annotation.

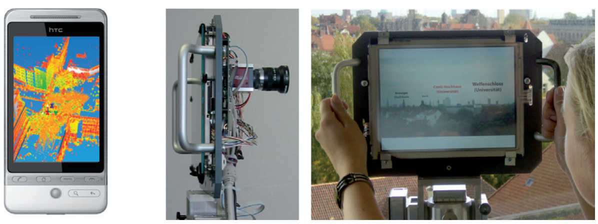

Figure 6: AR devices used: HTC Hero Smartphone (left), GeoScope (right)

4.3.1 Visualization: For the visualization of the acquired data we use a point based rendering (PBR) approach that can operate on the point data with minimal preprocessing. While many tools that operate on 3D models require a polygonal reconstruction of the surface, a visual depiction can be rendered directly from point data (Levoy et al., 2000).
For the acquisition application this has two benefits:
First, it is not necessary to construction (good) polygonal models before the information can be displayed – this is very desirable for models where (during the acquisition process) some parts maybe highly detailed and others only coarsely represented. It also results in a much simpler and faster way to present the data after acquisition. Second, the direct depiction of the data provides an intuitive presentation of the data density – to exploit this we have adapted existing point-based rendering techniques to be able to display either continuous surfaces (as is usually the goal in PBR techniques) or distinguishable point-sets. As the rendering of the point based data is very simple (each point is rendered as a splat) it can be easily implemented on a Smartphones and similar devices, especially if the data handling and preprocessing is handled on a more capable PC that is networked to the Smartphone. The effect of direct geometry rendering and the possibility to integrate secondary information like quality data can be seen in the Welfenschloss Example in Section 5.

4.3.2 Rapid Calculation of Quality Metrics: In order to determine the quality of the acquired data geometry analysis algorithms must be applied. Given the large data-sets this processing usually does not work at interactive speeds. One possible way to achieve the needed speed-up is the use of modern graphics processors (GPUs) that provide highly parallel data processing capabilities. In addition to the processing speed the possible speed-up through the use of GPUs also depends highly on the data organization. To establish the possible speed-up with the kind of data used in the acquisition we conducted experiments comparing the implementation of different algorithms on the GPU and CPU. To conduct the experiment we picked the calculation of k nearest neighbors (kNN) as an example metric. KNN is useful in many aspects, e.g. algorithms like triangle-mesh reconstruction use it for surface reconstruction and it can serve directly as a quality metric by providing a density value for each acquired point. However, it should be noted that the central goal here was not to develop a better KNN algorithm but to establish the possible speed-up with realistic datasets as a basis for applying the GPU approach to more involved processing and analysis algorithms later on.
The density d_P of point P is the inverted sum of the distances between P and the k nearest neighbors P_i of P.

$$d_P = \frac{k}{\sum_{i=0}^{k} |PP_i|} \quad (3)$$

The association of colors to the minimum and maximum density value (e.g. max density = green, min density = red) allows to visualize the calculated density values (see Figure 12).
We have implemented several algorithms for point set analysis on the GPU, using OpenCL to achieve platform independence. In a test setup on a PC with Intel Core 2 Duo E8400 with 3.0 GHz, 8 GB of dual channel DDR2 RAM and a Nvidia Geforce GTX 285 with 240 stream processors we compared performance between the GPU implementation using OpenCL and a C++ implementation on the CPU. As shown in Figure 7 a simple brute-force implementation of kNN the GPU calculation was 45 times faster, making the use of this quality measure on-site viable. More complex algorithms (e.g. partioned kNN) are possible and result in further speedup, but require more detailed tailoring to the parallel structure GPU to realize the acceleration potential. For a detailed discussion see (Eggert and Paelke, 2010).

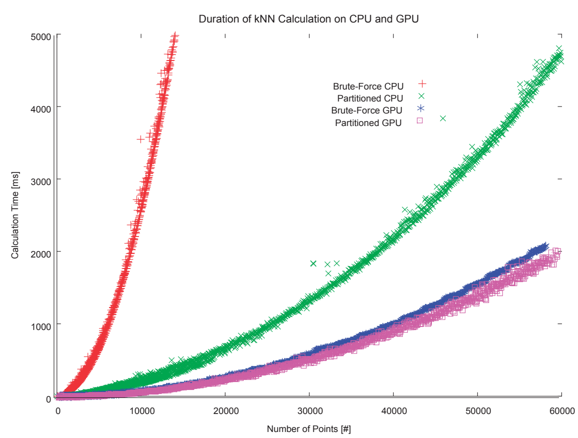

Figure 7: Runtime comparison between CPU- and GPGPU-based kNN implementations

5. EXAMPLE

The Welfenschloss (Figure 8) is a former castle in the northern part of the city of Hannover. It was planned by the architect Christian Heinrich Tramm and built between 1857 and 1866. Since the kingdom of Hannover ceased to exist as an independent entity when it was annexed by Prussia in 1866, the Welfenschloss was never used as a castle. In 1879 it became the main building of the University of Hannover (Pietsch, 2003).

Figure 8: the Welfenschloss (Photo: Andree Stephan)

In the following example we use the Welfenschloss as a test-case for demonstrating our methods.
Figure 9 shows an initial model of the Welfenschloss – in this case data acquired from airborne laserscanning. The data is sufficient to enable a rough orientation and thus initial mark-up of areas of interest, but lacks all the detail required for detailed documentation or presentation. Information of this kind is often available from airborne laserscanning, airborne photogrammetry or extruded cadastral data.

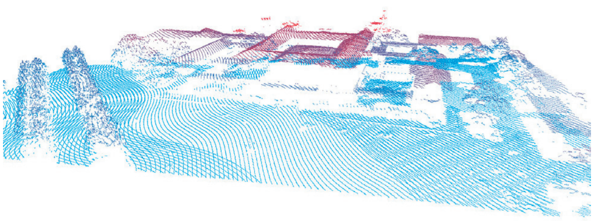

Figure 9: Initial model from airborne laserscan with color indicating height

To generate models that are suitable for documentation, analysis or presentation additional detail must be acquired and integrated into a coherent (geometric) model. We use a terrestrial laser scanner (Scanner Riegl LMS Z360I) to acquire this detail information on the geometry.

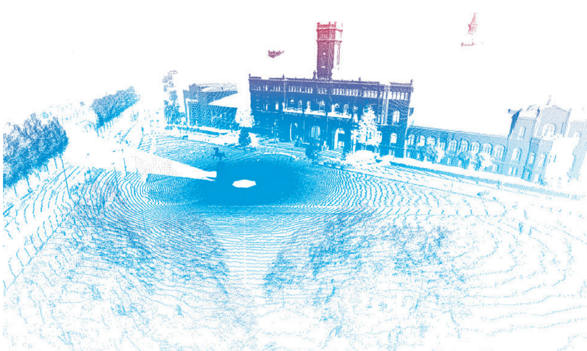

Figure 10: Terrestrial laserscan with color indicating height

Figure 11: Terrestrial laserscan with texture colors

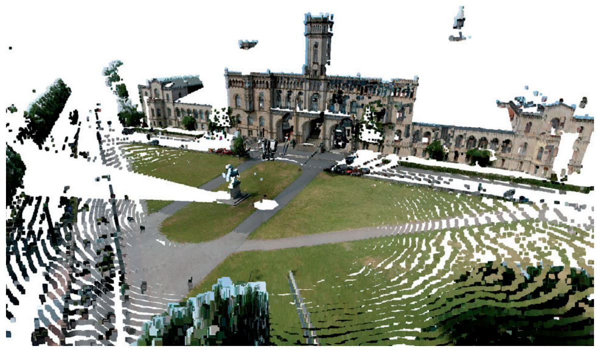

Figure 12: Terrestrial laserscan using splat-based PBR with texture colors

To check the data acquired on site both for coverage (completeness) and quality a rapid visualization is required. As described in section 4 we employ a point based rendering (PBR) approach that generates images like Figure 9-13 for display on smartphones, the GeoScope or Laptops. In the PB rendering of the pure geometry operators can get an intuitive overview of the coverage of the data acquired at a certain stage. Combing the rendering with the mark-up of areas of interest previously assigned by a content expert in the initial model allows an intuitive check for completeness. However, it is difficult to check the quality of the acquired data from a pure geometry depiction. Therefore, quality information like density is derived from the data and this can be integrated into the rendering (Figure 13).

Figure 13: Visualization of scan density.

Using this presentation a rapid check for completeness and quality with regards to the area of interest becomes possible.

6. OUTLOOK AND FUTURE WORK

Most heritage monuments are complex in their shape and span over wide areas. Therefore they require complex acquisition setups and very elaborate processing. Both consequences translate into high cost and reduced accessibility to laser scanning technology driven modelling. In this regards, this paper proposed efficient acquisition of data, efficient processing of the laser point cloud, and easy do display and interact visualization tools. The main focus here was on the acquisition process and primitive extraction. In this regards, it offered utilizing the range panorama concept as a means for both data integration and efficient feature extraction. The paper has proven that the basic technologies required for implementing a system for geometry acquisition with terrestrial LIDAR that adapts the resolution to the requirements using an AR based user interface. Using an iterative approach the individual components are currently refined, and integrated to develop additional and more complex algorithms for data analysis, fusion based on segmentation and presentation. In order to face the demands of on-site quality evaluation we employed GPGPU-based analysis-algorithm implementations. As a proof of concept we implemented an OpenCL-based k nearest neighbors (kNN) determination and used kNN as an example metric to indicate the point cloud density in each point.

Extension of this research will explore three areas: first, studying the effect of the new acquisition tools, gathering user feedback on the functionality of an AR user interface and the suitability of different devices to support them, especially comparing the use of smartphones and the GeoScope. Secondly, extending the functionality of the acquisition process and on-site modelling, incorporating the results from the user study and additional requirement from real world users. Specifically, we want to integrate enhanced quality measure requiring more complex analysis algorithms, advanced matching algorithms for multiple laser-scans that are usable "on-the-fly" and additional modelling functionality to support semantic annotation. The third research thread will focus on the use of the data gathered, addressing the presentation of the acquired models and interaction with them from a user perspective.

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Virtual Reality and Multimedia in Cultural Heritage

AN INTEGRATED APPROACH TO DIGITAL CULTURAL HERITAGE

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KEY WORDS: Virtual worlds, Cultural Heritage Visualization, London Charter

ABSTRACT:
This contribution relies upon a two year's educational and research project using Second Life (SL) as a teaching / learning platform. The project main goal was to investigate the added value of a multi-user environment in a multi-disciplinary and international context for learning about history, archaeology, acquiring a scientific approach and methodology to historical reconstruction and 3D visualization, as well as the skills to use different media technologies for communication and collaboration. We will briefly describe and critically assess the outcome of the project in order to stress the importance of an integrated model, spanning across all the phases of a cultural heritage project and involving different disciplines as peers, together with a set of internationally recognized best practices and educational programmes, to make significant advances in the field of cultural heritage research and dissemination.

1. INTRODUCTION

In July 2007, following a highly successful Erasmus placement of a student from the University of Pisa Digital Humanities degree (DH-Pisa) to the Centre for Computing in the Humanities (CCH) at King's College, the two institutions decided to jointly develop a "Digital Humanities" Island in Second Life (SL).

Given that both CCH and DH-Pisa offer modules in visualisation for the humanities, this was seen as a teaching and learning collaboration opportunity to develop a shared syllabus and associated teaching and learning resources for humanities visualization.

The development of joint cultural heritage projects was an additional perspective: DH-Pisa could provide CCH with access contacts, resources and authorisations necessary to undertake intrinsically valuable cultural heritage sites in Italy; CCH could provide DH-Pisa with access to additional cultural heritage visualisation skills, equipment and methodologies. Possible projects involved the complex in which "The Leaning Tower of Pisa" is situated, the roman theatre of Lucca, and the medieval walls of Pisa. These modelling and visualisation projects were meant to study, collaboratively, the methodological implications of the SL platform in relation to current developments and debates, especially The London Charter (The London Charter, 2010), and to identify particular issues and opportunities that SL raises regarding London Charter implementation. It would explore whether a more or less fixed set of visualisation and documentation conventions for humanities and cultural heritage uses of SL would be desirable, or whether a variety of approaches should be allowed to emerge in tandem with the technology as it evolves. The collaboration would allow the researchers to draw on their shared teaching and learning activities, developing and observing a wider range of case studies with student groups, and providing a well-defined research agenda and set of approaches according to which participation by other humanities and cultural heritage researchers in SL, including the EPOCH network of excellence (EPOCH, 2010), could be encouraged.

Between 2007 and 2010, King's and Pisa made notable advances in realizing each of these objectives. Together, they established "Digital Humanities Island" (DHI), complete with welcome centre, teaching, learning and display spaces and interactive guides, and successfully hosted a number of virtual exhibitions and "mixed-reality" live events; in 2007-8, they created several proof-of-concept cultural heritage visualizations in SL including of Galileo Galilei's Laboratory and the Leaning Tower of Pisa; in 2008-9, they carried out a successful teaching and learning collaboration on ancient maritime archaeology; and in 2009, they secured funding for, and completed, a project on applying the London Charter (discussed below) within SL.

The story of our collaboration thus far is one that encompasses ideals and errors, hopes and frustrations, achievements and, today, a renewed and revised sense of possibilities. This paper will give an account of these experience and reflects upon what it has taught us about the use of virtual worlds in humanities teaching and learning and, more in general, about cultural heritage visualization projects. In particular one of the important lessons we learned is the importance of an integrated model, spanning across all the phases of a cultural heritage project, involving different disciplines as peers, a scientific approach, a set of internationally recognized best practices and educational programmes in order to make significant advances in the field of cultural heritage research and dissemination.

2. EDUCATIONAL BACKGROUND

The University of Pisa offers a degree in Digital Humanities, an interdisciplinary study program in which students receive a solid education in humanities together with the technological skills and methodologies to master the tools for processing cultural contents in different digital forms. The study program provides competences and skills for jobs which rely on creative expression by means of new technologies such as: virtual environments and augmented reality, graphics, 3D modelling, animations, multimedia production, digital audio, computer games, computer art, interactive performances and exhibitions. Given their specific background, students have the necessary background to play an active role in the construction of artifacts in SL.

The Centre for Computing in the Humanities at King's College London offers a taught Masters in Digital Culture and Technology. In an elective module called Applied Visualization in the Arts, Humanities and Cultural Heritage, students study significant examples of computer-aided, applied visualization in teaching and research contexts, encompassing a wide range of purposes, technologies, approaches and methods and, working under the guidance of members of King's Visualization Lab (KVL), design and carry out a specific visualization project.

KVL has nearly fifteen years of expertise in the reconstruction and visualization of cultural heritage and a significant profile in SL. In June 2007 KVL commenced work on its first major, teaching and learning project in SL, Theatron3 (Childs, 2009). Theatron3 transformed the team's earlier, award-winning Theatron project (http://www.kvl.cch.kcl.ac.uk/theatron.html) into a range of content-rich, research-based virtual environments in SL including19 milestones in European theatre design from the Theatre of Dionysus at Athens to the Teatro Olimpico at Vicenza (Denard, 2005). Each virtual theatre has extensive associated historical and interpretative materials delivered through location-sensitive, media-rich Heads-up Displays (HUDs) containing in-depth contextual and interpretative educational resources, as well as a framework enabling users to create their own versions of the HUD responsive to their own teaching learning objectives.

3. HUMANITIES VISUALIZATION PRINCIPLES

KVL is known for having instigated, and for continuing to lead the development of The London Charter for the Computer-based Visualisation of Cultural Heritage (London Charter) – a set of internationally recognised principles that provides a framework ensuring that digital visualisation methods are, and are seen to be intellectually rigorous and robust. The London Charter insists upon intellectual accountability, or "transparency" that enables subject communities "to evaluate the choice of a given visualisation method, and how it has been applied in a particular case without having to rely exclusively on the 'authority claims' of the author" (Beacham et al. 2006). The current version of the London Charter (2.1, February 2009), available in English, Italian, Spanish, German and Japanese, sets out six main principles (each with several sub-sections):

Principle 1 – Implementation: the principles of the London Charter are valid wherever computer-based visualisation is applied to the research or dissemination of cultural heritage.

Principle 2 – Aims and Methods: a computer-based visualisation method should normally be used only when it is the most appropriate available method for that purpose.

Principle 3 – Research Sources: In order to ensure the intellectual integrity of computer-based visualisation methods and outcomes, relevant research sources should be identified and evaluated in a structured and documented way.

Principle 4 – Documentation: Sufficient information should be documented and disseminated to allow computer-based visualisation methods and outcomes to be understood and evaluated in relation to the contexts and purposes for which they are deployed.

Principle 5 – Sustainability: strategies should be planned and implemented to ensure the long-term sustainability of cultural heritage-related computer-based visualisation outcomes and documentation, in order to avoid loss of this growing part of human intellectual, social, economic and cultural heritage.

Principle 6 – Access: the creation and dissemination of computer-based visualisation should be planned in such a way as to ensure that maximum possible benefits are achieved for the study, understanding, interpretation, preservation and management of cultural heritage.

4. INTERDISCIPLINARY EDUCATION

In a series of separate and joint projects between October 2007 and June 2009, DH-Pisa and King's College built, on DHI, Galileo Galilei's Laboratory, the Leaning Tower of Pisa, the Tower of London, a Roman ship (Alkedo) and an orientation centre, "Arketipo", equipped with a conference room, offices, tools for organizing meetings, information panels and an interactive guide called "IUMI". All the "builders" were students, under supervision and guidance of the teaching staff, and they did everything – the modelling and the development of tools – in the few months available within the curriculum.

The partners used SL not only as a building yard, but also as a real area of collaborative work, given that the organizational and planning meetings were held in the virtual world as part of the practical lessons; the usefulness of SL as a platform for meetings and workshops indicates its significant value within the educational domain.

The main barriers were thus not so much cultural or linguistic in nature, but rather reside in the concrete bureaucratic and administrative problems that affect the organization of joint courses in two (or more) universities: the differences and rigidity in timelines and schedules, unclear relationships between face-to-face lessons and independent study, the difficulty in accrediting the time students and staff spend working in the virtual environment, and the challenge of getting university authorities to understand the nature and benefits of these modes of teaching and learning as well as the shifts in working practice and assessment models they imply. If these barriers were reduced or eliminated altogether, SL could actually constitute a practical and economical platform for internationally-taught modules which would become "naturally" interdisciplinary because they would require students to learn and use a shared language: not only the spoken language, but the specialized language of each subject material treated too (History, 3D Modelling, Art, Architecture, Computer Science).

The great interdisciplinary value, as well as potential limitations, of a Multi-User Virtual Environment (MUVE) such as SL lies in the fact that, within it, students can learn by doing, complementing the combination of reading/writing or reading/explaining that characterizes the vast majority of university courses in the humanities (Kemp & Livingstone 2006; Joseph 2007; Ondrejka 2008; Wankel & Kingsley 2009; Molka-Danielsen & Deutschmann 2009; Gütl et al. 2009).

The construction of the Arketipo learning and information centre; the IUMI interface; Galileo's Laboratory; the Leaning Tower of Pisa; the Roman ship, Alkedo; and the East Wing of Somerset House, London enabled students to acquire, share and improve knowledge and skills not only in history and archaeology, but also in 3D digital modelling; digital video and audio; writing; reading aloud; human computer interaction and web design; as well as advanced skills in independent learning; multi-partner collaboration; project planning and management; collective problem solving; implementation of relevant methodological standards; communication across disciplinary, cultural and technical divides, an opportunity to assess the utility and potential of a technical platform for cultural content creation, technical development and exploitation.

5. CREATING DIGITAL CONTENT

In the following, we briefly review some of the projects developed in order to outline the ideas and concepts emerged from this experience.

5.1 The Arketipo educational center

Arketipo is the conference centre and meeting place of the DHI community. We envisioned the centre to become an effective bonding place where the reference community could meet and engage in a number of activities introducing them to the humanities computing culture. The chief builder, Francesco Genovesi put a lot of imagination, care and effort in designing and building Arketipo; the result was a grandiose building, high quality when compared to the standards of SL (Figure 1).

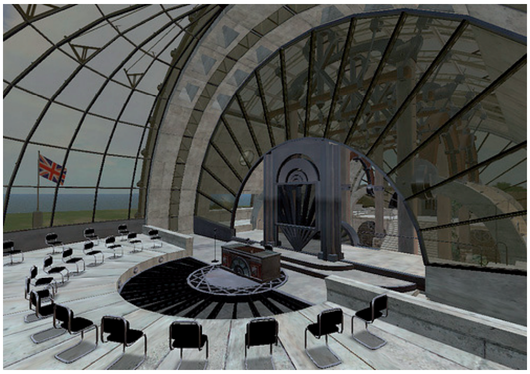

Figure 1: Arketipo

Arketipo, however unique, offers the virtual counterpart of traditional teaching places and tools: an auditorium, meeting places such as the garden, an exposition space, offices, slides projectors, blackboards. Multifaceted information services integrate in SL information sources already available in the university setting: web site, blog, forum, mailing list, RSS feeds.
Special care was devoted to designing effective interactive devices and natural solutions for the “affordance” of objects (Norman, 2002). New entry students and occasional visitors land exactly in the middle of the arrival platform, in front of the entrance hall of the centre. They find before them a set of four pillar-like interactive panels: Rules, Teleport, Information, Iumi. When approaching any of these panels, within a range of 5 meters, a round-rotating script associated to the buttons is enabled and a rotating text appears around the buttons, explaining their function. This is the only *non-static* element and is especially designed to immediately catch user's attention on the action to be performed. All interaction effects were tested on different subjects and proved easily understandable and intuitive.
The first floor hosts a big semi-circular auditorium for conferences, fully equipped with a screen for slide and movie projection, blackboards, a teaching desk and a number of chairs for the audience (Figure 1). The ground floor is occupied by a garden dominated by the *tree of knowledge* rising among ancient ruins. The branches of the tree form the shape of a hand stretching towards the sky. You can sit on the tree to chat with fellow avatars (Arketipo blog, 2009). Arketipo’s exhibition hall is a place for showing the best projects completed by the students.
In the underground floor there are a number of offices, fully equipped with uniquely designed desks and chairs, where professors can meet with students. Contact hours are advertised on message boards in the atrium in front of the offices. The underground floor also hosts a special secret room where the students can find other student’s notes and suggestions on how to pass the exams.
More complex is the solution adopted for showing 3D models of buildings. Since the number of prims (“primitives” - the basic building blocks used to create three-dimensional content in SL) is limited, we cannot afford to display all the constructions permanently on the island. The solution was to acquire and deploy a mechanism for displaying them on demand, a so-called *rezzing panel*, put in the space outside Arketipo.

5.2 The Leaning Tower of Pisa

Elisa Ciregia, a graduate student of Humanities Computing at the University of Pisa (Ciregia 2009) undertook to build a London Charter-compliant visualisation of the famed, “Leaning” Tower of Pisa. The central aims of Ciregia’s project was to test the capabilities of SL as an environment for both faithfully representing and providing, virtually, widespread public and information-rich access to precious monuments.
Ciregia’s model was rooted in her study of plans and technical documents relating to the Tower held by the Department of Civil Engineering at the University of Pisa. However, despite the effort to ensure the fidelity of the model to the original, the work presented many problems. The first challenge was the policy, then in force on DHI, that heritage visualisations, in the interests of consistency of user experience, should be built at 1:1 scale (using the in-world unit of measurement).

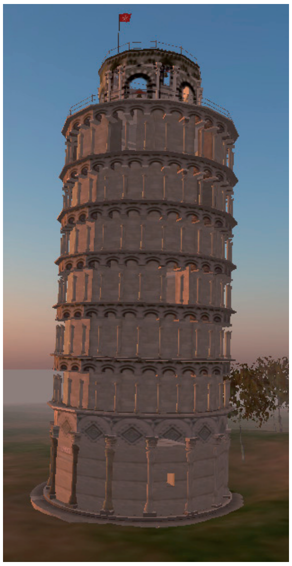

Figure 2: The leaning tower

This stipulation, together with the extraordinary complexity of the Tower, would have required a number of prims many times in excess of that available within SL in general and in the shared space of DHI in particular. As a consequence, Ciregia had to devise ways of greatly simplifying the model. Rather than detailing each of the unique column capital designs on the actual Tower, for example, Ciregia was forced to use a single, standardised capital. Similarly, entering the “virtual” Leaning Tower, one finds it completely hollow; where the 296 stairs should be is, instead, an interactive teleport tool inviting avatars to beam themselves up to the top floor (Figure 2).

While SL imposes particularly stringent constraints on the modelling process, every type of modelling software, in fact, even the most accurate, involves operational decisions that affect the quantity and quality of information vehicles: there is no perfect model. To the question: "Can SL successfully accommodate and communicate to mass audiences high-quality, faithful, representations of complex, large-scale monuments?" the project established some significant limitations, and in the process became a wonderful occasion to add to the bouquet of interdisciplinary learning other flowers, most notably restoration theory and practice, and the methods and problems of popularising cultural heritage. These extended observations and understandings have to become the starting point for future conversations about virtual heritage representation.

5.3 Galileo Galilei's Laboratory

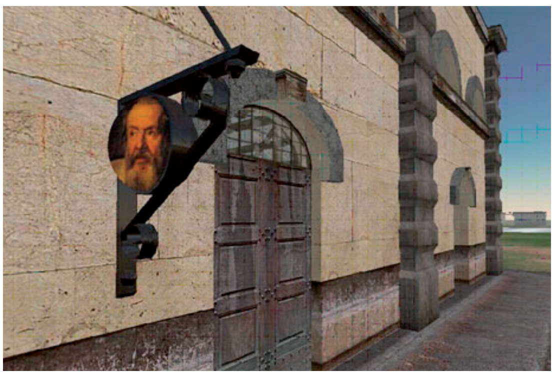

Figure 3: Galileo Galilei's laboratory

The next project followed, in some ways, a similar path to the Tower of Pisa project, since this virtual building too was "enriched" by notecards and audio files; but it also presented different challenges and problems. *Galileo Galilei's Laboratory* is a virtual representation of an actual building in the old slaughterhouse area of Pisa dating to the early 900s that today hosts the Museum for Computation Instruments (*Museo degli Strumenti di Calcolo*) in which the Galileo Galilei Foundation stores and displays to the public several Galilean experiments.
The building and the virtual experiments were modelled as part of a taught module in *3D Graphics*, while students studying *Introduction to Historical Studies* produced audio and text files relating to the life of Galileo, his experiments and the history of science. In the *3D Graphics* module, students first took photographs of the real Laboratory and of the Museum's physical reconstructions, designed by Professor Vergara Caffarelli, of experiments described by Galileo Galilei. Using these photographs both as primary reference materials for modelling and as sources for textures, they undertook to build their own virtual reconstructions, in SL, of the "inclined plane", "pendulum", "inclined plane with pulley", "double pendulum" and "hydrostatic balance" experiments. Meanwhile, the students taking the *Introduction to Historical Studies* module undertook extensive readings on the life of Galileo and on the importance of his works in history of science. They then wrote, and recorded as audio files, informative texts suitable for the general public which the *3D Graphics* students, as well as publishing them through web-pages, also embedded in the virtual library so that SL users could read or hear them by clicking on the experiments and pictures hanging on the walls (Figure 3).

For the students of *Historical Studies*, the collaborative, virtual world-orientated process drew upon the traditional skills of reading books and articles, but also shifted the emphasis of these activities by conjoining them with the additional tasks of: (a) selecting from rich, complex and deep historical materials subsets to be deployed in the context of a particular exhibition/installation; (b) summarizing, explaining and correcting sources to create new texts appropriate for a specific audience; (c) adapting content for use as hyper-linked segments, rather than as linear narratives; (d) authoring and publishing historical content for the non-print technologies of the digital, mass media age.
The virtual world environment also changes, and augments, the learning experience of students of *3D Graphics*. Firstly, and most important, their standard workflow and conventional aims of modelling have to be redesigned to make allowance for a collaborative, real-time, avatar-based, content-creation environment. A particular challenge in this respect is that of understanding the implications of working in an environment that, unlike most 3D modelling tools, is not designed to provide industry-level graphical quality and performance, but rather aims to enable user-generated content and social interaction via a form of virtual embodiment. In this context, even the very aims of graphical representation need to be reconsidered.
Other major challenges, or learning opportunities, are those of devising approaches to digitally representing three-dimensional cultural heritage that anticipate the requirements of both the user and the avatar. In the games industry, for example, the virtual terrain and the built environment are laid out to optimise ease of navigation and viewing. By contrast, real-world monuments, with their frequently complex, confined and irregular interior spaces, are rarely so obliging to the avatar. Computer games also typically do not aspire to hold themselves accountable to high standards of historical integrity, or to deliver extensive, detailed historical information. Historical visualisation, however, operates in a domain in which the conventional means of communication is lengthy, linear text; the heritage visualisation strategy must therefore also include plans for communicating the relationship of visualisation to the historical sources from which it derives, for adapting historical materials into genres and formats that are appropriate to the virtual world, as well as for providing access to them through non-intrusive, intuitive interfaces.

5.4 The Alkedo ship

The very significant success of the Pisan project on Galileo's Laboratory, with its combination of the two very different "cultures" of modules on *Historical Studies* and *3D Graphics*, both prompted us, at King's, to emulate its collaborative approach in the next academic session (2008-9), and also gave us the confidence that the virtual world could enable us to do what we would never previously have attempted, namely: to link modules in two different institutions in two different countries.
In 1998, lying in the soft silt of an ancient river bed on the outskirts of Pisa, was found the remains of several boats spanning 1,000 years of maritime history from the Augustan age to medieval times, all wrecked, at one time or another, by violent tidal floods. One of these, Ship C, is the only Roman vessel ever to have been found with a name carved into her timbers: her deeply-incised Greek letters clearly spell out the word "Alkedo" – Seagull. The Alkedo is a 13m-long vessel in the shape of a small, sail and oar powered Roman warship, which may have acted as a coast-hugging patrol boat, or a shuttle designed to carry personnel and supplies from port to

larger, sea-going vessels in the fleet, or – perhaps retired from active service – the pleasure boat of a wealthy local. The hull and its contents have been lovingly and painstakingly preserved by the Centre for Restoration of Waterlogged Wood (*Centro di Restauro del Legno Bagnato*) at the Shipyard of Ancient Pisan Ships (*Cantiere delle Navi Antiche di Pisa*), and the ship will soon be the subject of a display in the new Museum of Ancient Pisan Ships (*Museo delle navi Antiche* di *Pisa)*, soon to open on the banks of the Arno in Pisa. Finally, the Centre for Restoration of Waterlogged Wood had also created a large-scale, physical reconstruction of the Alkedo, which would provide both a reference point and a rival hypothetical interpretation in relation to which we could situate our own virtual, reconstructive efforts.

Due to logistic problems we devised a project with two associated, but autonomous, phases: in the first semester of 2008-9, students at Pisa would model, in SL, the archaeological remains of the Alkedo; then, in the second semester, the students at King's would create, also in SL, a virtual reconstruction of the Alkedo as it may originally have been in its prime (Figure 4).

This affiliation of the two "Alkedo" projects became significantly more substantive with the inception of an additional new joint King's-Pisa initiative: the *London Charter in Second Life* project (The London Charter in Second Life, 2010). Martin Blazeby (King's) and Beatrice Rapisarda (Pisa) applied for, and received, funding under the British-Italian Partnership Programme for Young Researchers, 2008-9, a joint initiative of the Italian Ministry of University Education and Research (*Ministero dell'Istruzione dell'Università e della Ricerca*) in collaboration with the Conference of Rectors of Italian Universities (*Conferenza dei Rettori delle Università Italiane*) and the British Council. The funding enabled Blazeby and Rapisarda to convene a series of workshops in Pisa and London designed to develop tools, guides, a heritage visualisation ontology and visual conventions to aid the implementation of *The London Charter* in SL.

In 2008-9, through the Alkedo project, we trialled, and subsequently in 2009-10 consolidated, the following combination of theoretical and practical tutorials. Throughout the semester, students attend a weekly, two-hour, traditional seminar which, in addition to discussing the history and theory of humanities visualisation, provides tuition in the principles and practice of project management, and offers hands-on project review sessions, in which the tutor, Denard, helps the students to develop and monitor their project plan as the work unfolds, and to keep their activities in dialogue with both the *London Charter* and the specific assessment criteria of the module.

When the students began to work on the Alkedo itself, it became clear that the principles of interdisciplinary learning observed in the case of the previous year's recreation of Galileo Galilei's Laboratory remained valid: students engaged in the modelling work had to learn aspects of Roman-era shipbuilding, the morphology of the Pisan coast over time, and of marine archaeology excavation and preservation techniques, as well as how to make these concepts and materials accessible to a wider audience through the creation of a website and documentary. Each student was responsible for some combination of defined tasks including: project management; historical research; translation into English of Italian sources; archaeological data acquisition and analysis; liaison with subject experts; in-world modelling (of interiors and exteriors); 3D Studio Max modelling and creation of sculptured prims ("sculpties") in SL; texturing; scripting behaviour of in-world objects; in-world visitor interface design; 3D animations; video documentary creation; wiki creation; website design; Facebook page creation; publicity materials creation; glossary compilation; copyright management (Alkedo project, 2009).

The model of the Alkedo that the students produced in SL was an impressive achievement: despite the limitations, as a modelling platform, of SL, through a combination of ingenuity and perseverance, the students meticulously captured the irregular contours of the boat, each rib and plank of the hull being composed of several, painstakingly measured and placed prims. Scripts were attached to oars and sail to evoke the vessel's means of movement.

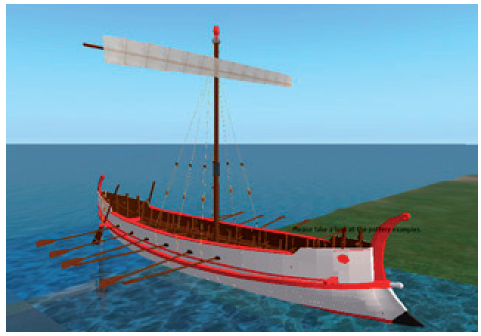

Figure 4: The Alkedo ship

The project team conducted numerous experiments to determine successful ways of publishing documentation of the visualisation process that would render the visualisation "intellectually accountable", or "transparent", as stipulated by the *London Charter*. The challenge was to find an approach that would not be unduly intrusive for the casual visitor, but which would allow interested users to drill down to highly detailed documentation providing full "transparency". The solution was combined in-world "hotspots" – detectable only by a change in cursor icon – which, when clicked, offer both notecards with information about the individual component in question and offering a live link to a webpage where was presented full, illustrated documentation of both the evidence on which the component was based, and of the process of interpretation and visualisation. The whole process of planning, research and modelling was captured via a wiki (Alkedo Project wiki, 2009) while a multilingual, interactive panel situated beside the SL model directed visitors to a separate website designed to present the project and its methodology to the public (Alkedo Project website, 2009). The integration of product and documentation of process continued through to the brief audio-visual documentary created by the team (Alkedo Project video-documentary, 2009), which included footage of work in progress, animations illustrating topographical changes in the Pisan coastline over time, and a commentary on the theory and practice of implementing the *London Charter*. Finally a formal, 33-page report (available through the wiki) recorded and reflected upon the project's aims, process and outcomes.

This focus on dissemination within the learning process is consistent with best practice within the field of historical visualisation, which asks those engaged in creating digital representations of cultural heritage to attend to the value that their efforts have, beyond their own immediate contexts, for wider society.

This sense of achievement is not without foundation; later this month, tutors from both Pisa and King's will meet with the Director of the Museo to take forward, we hope, plans to create a permanent, public visual installation on the Alkedo based on our students' work in SL.

6. IDEAS FOR AN INTEGRATED APPROACH TO DIGITALIZATION OF CULTURAL HERITAGE

Owing to the experience described above, we have established proof of concept for inter-institutional pedagogical collaboration in the areas of digital humanities and digital cultural heritage.
This success, when combined with the "borderless worlds" that the Internet creates, not least through virtual worlds, suggests that this model could, with significant, widespread benefits, be extended to encompass *both* a more widely-defined vision of cultural heritage research, documentation and communication *and* an international network of institutions who have existing commitments in these areas.

The vision has a number of components:

i. We need to create a conceptual model of how, if an integrated interdisciplinary approach were to be adopted, the entire set of possible modes of engagement with tangible and intangible cultural heritage – both "traditional" and digitally-enabled – could extend and improve each other.
ii. We need to identify and carry out pilot projects exploring and demonstrating how sets of, currently isolated, cultural heritage practice could benefit each other by identifying and exploiting potential points of convergence.
iii. From this, we need to devise a second conceptual model: of an international cultural heritage curriculum providing training to postgraduate students that will result in graduates, and new cultural heritage professionals, academics and communicators (both scientific and popular), who have conceptual and practical competence in implementing a fully integrated approach to cultural heritage.
iv. Finally, we need a mechanism for iteratively identifying potential cutting-edge, emerging best practice in cultural heritage practice, for working out how it could be extended and improved through integration with other cultural heritage practices, for testing implementation of the newly integrated practice, and finally for developing and disseminating teaching materials that allow the new practice to be added to the international curriculum.

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METAVERSE COMMUNITIES AND ARCHAEOLOGY: THE CASE OF TERAMO

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KEY WORDS: Teramo, Collaborative Virtual Reconstruction, Archaeology, OpenSimulator, 3DMetaversity

ABSTRACT:

In 2009, a joint research project among the University of California Merced, the City of Teramo and the Institute of Technologies Applied to Cultural Heritage (National Research Council, Rome) started with the goal to communicate virtually the archaeological context of the city, on the basis of the key archaeological areas of the urban network. The title of the entire project is *Teramo: a city virtually "dressed"*. The main goal is the creation of a network of digital installations across the city based on different digital technologies and mobile systems.
Despite the importance of the city from the archaeological point of view, the fragmentation of the sites, mostly hidden or de-contextualized, and the difficulties to communicate them in broader sense, make difficult an adequate cultural communication from any point of view: scientific, educational, social and touristic. Therefore the Virtual becomes a social connector for the local communities, stimulated to re-discover their territory, and for visitors, involved in a more effective learning experience. Is a *metaverse*, such as OpenSimulator, able to develop a social sense of presence even in a virtual world? Is it possible to construct new social narratives by virtual worlds? This paper is related to an application developed in the open source platform OpenSim for a virtual community of users embedded in the cyberspace. This application is specifically created for the virtual island *3DMetaversity*, an open source project hosted at the CINECA, Supercomputing Center of the University of Bologna. At the current stage of the project two key ancient Roman monuments of the city, the Theatre and the *Domus,* have been reconstructed; in addition, the creation of a virtual library, *Virtuoteca,* constitutes a meta-space for the communication of archaeological contents.

1. THE PROJECT

1.1 Introduction

This paper discusses the preliminary results of an application developed for OpenSimulator platform within the virtual universe of *3DMetaversity*, an open source environment for 3D virtual communities (hosted at the Supercomputing Centre of the University of Bologna). The case study is the Italian city of Teramo and, more specifically, the reconstruction of the archaeological sites in the Roman period.
In 2009, a joint research project between the University of California Merced, the City of Teramo and the Institute of Technologies Applied to Cultural Heritage (National Research Council, Rome) started with the goal to communicate the cultural contents of the city through digital technologies, on the basis of archaeological information about the early urban network. The title of the project is *Teramo: a city virtually "dressed"*, as it was presented in a public conference in 2007 organized by the municipal administration.
Despite the archaeological value of the city, the fragmentation of the sites, mostly hidden or de-contextualized within the posterior urban structure, and the complexity of their systemic communication, make it difficult to understand the Roman Teramo (*Interamnia)* from any point of view, scientific, educational, social and touristic. In this scenario it is more appropriate to generate an integrate communication system (scattered in different platforms) rather than to concentrate the applications within the same digital domain. In fact the Italian CNR-ITABC has realized different multimedia-virtual installations in the archaeological site of St. Anne and in the archaeological museum (case studies: Roman *Domus* and the ancient cathedral of Santa Maria Aprutiensis); the result obtained is the diversification of digital contents and interactive activities.
For what concerns our contribution, the virtual island was created in the GRID server *3DMetaversity* developed in OpenSimulator. OpenSim is a cross-platform server application which can be used for the creation of 3D virtual worlds accessible through the Internet. The software has a modular architecture and permits to expand its configuration, even via third-party add-ons, in order to obtain a highly customizable simulation environment. OpenSimulator is open source and released under a BSD License. Therefore this technology is extremely versatile and effective for both academic and commercial purposes.
The design of the cyber-space is represented by a virtual tree with different models located at different levels, as virtual "branches" and models:

- Roman Amphitheater. Virtual Reconstruction of the archaeological site.
- Roman Theater. Reconstruction of the structure with the possibility to host virtual performances by avatars/actors.
- Lion's *Domus*. Reconstruction of the Roman mosaic with metadata and storytelling of the scenes.
- Complete reconstruction of a Roman *Domus* in order to explain the original context of the Lion's *Domus*: architectural space, structure, furniture, gardens.
- Virtual Library (*Virtuoteca*). A space for exhibitions able to host movies, posters, pictures, slide show related to the history of Teramo. This library will contain additional

information on other archaeological/cultural sites of the city not specifically reconstructed in other parts of the island.

- Blog 3D. A space open to all the visitors where it will be possible to post messages, a book for comments and, in the future, pictures, movies and didactic materials.
- Auditorium. A multimedia space for conferences, workshop, presentations, seminars, meetings.

The virtual city of Teramo in OpenSim is an attempt to motivate different cultural communication and discussions among diverse stakeholders (citizens, tourists, students, museums visitors) by 3D social interactions (fig.1).

Figure 1: Avatars gathering information about the *Domus*

The experience in *3DMetaversity* can promote a multidisciplinary dialogue and discussion, especially addressed to the schools, on the multilayered archaeological evolution of the city.

1.2 An OpenSimulator-based cultural Metaverse

The incremental number of virtual and participative activities in the cyber space creates new forms of social communication and interactions. In this scenario the concept of *metaverse* is important in order to understand how the relationship between virtuality and cultural communication is changing, and indeed how this phenomenon plays an important role in the field of virtual heritage. A *metaverse* can be defined as a virtual place where a *cyber community* of individuals *can share social interactions* without the restrictions of the physical world. According to Rădoiu (2008) the main characteristics useful to distinguish a *metaverse* are scalability, different access levels, synchronous communication between agents, a set of social rules and customs shared by users, and economic activity. More specifically, we adapt the concept of *metaverse* to suit the field of cultural heritage and define *cultural metaverse* as a grid of online 3D spaces in which users, embodied in avatars, interact in order to co-operate in the process of creation of a specific and shared cultural models. In recent years these forms of network communication have created novel paradigms for contemporary cyber culture, producing a fertile context for academic digital education (Vilela, 2010). The *cultural metaverse* developed in this project is aimed at the v*irtual musealization* of the Roman city of *Interamnia*. In a preliminary phase the work was concentrated on 3D visualization of significant archaeological sites characterizing the urban landscape during the Roman Period: the Roman Theatre and of one of the Roman *Domus*. In a second phase of the project a virtual tour of the Roman Anfitheatre and *Domus of Lions*, other two important monuments of the city, will be available as well. In order to pursue cultural and institutional goals of our virtual archaeology initiative, OpenSimulator was chosen because it receives the support of a vast and active community of developers who participate in the implementation of a server application that allows for the creation of virtual worlds. The use of this platform opens new scenarios in the *metaverse* applications, dominated for over a decade by proprietary software such as Second Life (SL) which has high costs of activation-maintenance, and also restricted possibilities of management. Thus, our choice was, initially, determined by the need to identify an efficient and alternative model of production and visualization for online 3D cultural contents. OpenSimulator is used by many research groups because the great versatility of the server application and the relative easiness of implementation of *metaverses*. Let us take a step back and describe, in brief, some of the specifics of this online 3D simulation environment. OpenSim is an open source cross-platform server technology that permits the creation of stand-alone and online virtual worlds. The development of OpenSim started in 2007 when Linden Lab Inc. decided to release the source code of Second Life grid and Second Life viewer under an open source, BSD license. This crucial event made it possible to start the development of an alternative server platform accessible from many different types of client software, using multiple protocols. Hippo Viewer, Meerkat, Emerald Viewer, Snowglobe, and SL viewer are the open source clients for OpenSim we tested in our project (fig.2).

Figure 2: Emerald Viewer, one of the clients for OpenSimulator

At present there are also many other viewers available for this virtual world technology, each one presenting different features. In particular the Dale's viewer is the only SL and OpenSim client supporting stereoscopic visualization. OpenSimulator and Second Life, necessarily, present many analogies in terms of user/agent/avatar management, primitive-based real-time 3D engine, and grid-based online simulation, but also some differences. SL only operates in *Grid mode* performing UGAIM (User, Grid, Asset, Inventory, and Messaging) services through the Internet and is submitted to a global grid manager, controlled by Linden Lab Inc.. OpenSim can be otherwise installed in a local machine, and runs in *Stand-alone mode* (Fishwick, 2009). This feature permits, for example, a cultural institution such a museum, to have its own *cultural metaverse* existing only on the local network. Such condition gives the museum and system designers the possibility to manage the data and to have a deeper control on the simulation process. At the same time it gives the system designers a more complete management on their own cultural communication projects. OpenSim can also operate in *Grid mode* and *Hypergrid mode*. This last operational instance can implement independent regions interconnection and the teleporting of avatars. Therefore different and independent virtual reconstructions can now be interconnected by an OpenSim *cultural hypergrid* and spread out in Internet. The great perspectives of OpenSim as research and education platform derive from the flexibility and modularity of its open source architecture. Besides supporting SL total compatibility, OpenSim permits the installation of add-ons and extra modules that help users create tailored virtual worlds using the most appropriate and convenient technologies. Thanks to the free availability of the source code of OpenMetaverse library, OpenSim ensures enormous possibilities of customization and integration with different technologies. Good examples are the *autonomous agents' systems* developed by researchers from University of Tokio, using OpenMetaverse Library and Artificial Intelligence Mark-up Language (Dohi, Ishizuka, 2009). Another example is the integration of OpenSim with third-party in-world assets search engines or web search engines developed by University of Arkansas (Eno, Gauch, Thompson, 2009). All these features make it possible to define OpenSim as a promising technology for virtual-cyber archaeology and predict a wide diffusion of this open source cutting edge technology in the near future. The official website of OpenSimulator project is http://opensimulator.org/.

1.3 OpenSimulator VS Second Life

In this section we reflect upon two simple questions: what is the level of software accessibility for use by cultural or academic institutions? What is the start up cost for implementation of a *cultural metaverse* through OpenSimulator? In the field of online virtual worlds the principal competitor of OpenSimulator is Second Life. We tested SL in a previous research project called *La Villa di Livia* (Forte, 2008). Now that we have experience working on a project in SL we can compare these two technologies and determine which provide the best cost/benefit.

As previously mentioned, SL is a commercial technology which entails costs associated with the purchase of digital land (server space) and its maintenance. Besides this, extra costs derive from the 3D modelling and texturing of buildings and avatars, and from the development of interactive activities for user involvement. The activation cost of a SL grid depends on the purpose of the initiative: at present the price of an undeveloped full private region is $1000 and its monthly maintenance fee is $295 (<http://secondlife.com/land> accessed on 08/12/2010). For educational or non-profit organizations the cost decreases to $700 and $147.5. Occasionally a 3D agency is also required to design, build, and manage the virtual world. While our team was able to manage the development of the *archaeological virtual environment* in the *Villa di Livia* project, we were still required to pay *Linden Lab Inc.* all the fees relative to the activation and maintenance of the server space.

In contrast to SL, OpenSimulator is an open platform; it permits users to avoid all the fixed and monthly costs, because an OpenSim-based *cultural metaverse* can be installed on a server owned and managed by a cultural/educational institution. Therefore the costs associated with the utilization of OpenSim are relatively low. This is because such a technology only requires the purchase of a computer (a basic server machine costs around $1000), the payment of a static IP address (less than $50 per month) and the wage of an OpenSim skilled computer scientist. While in SL there is a fee for the uploading of each texture, sound, and animation, in OpenSimulator the development of buildings, objects, and avatars have no additional costs. Another fundamental difference between these two technologies is the level of sustainability (exporting of the contents to other platforms or availability of source code, API, and software development kit) that is high in OpenSim and low in SL.

Our experience in the usage of both platforms underlines that a gap I still present between them. Second Life is in fact much more reliable and stable than OpenSim. This is because *Linden Lab Inc.* constantly invests resources in the maintenance and improvement of the application, assigning the development and debugging of the software to a team of professionals.

The possibility to reach a broader public is another advantage of Second Life: an average of about one million users (residents) connect to this platform, on a monthly basis (<http://secondlife.com/statistics/economy-data.php> accessed on 08-12-10), making it the most popular and used *metaverse* of the world.

Our initial conclusion is that, while SL can be defined as a more mature and widespread technology, the high start-up costs and the low level of software sustainability leave this platform more suitable for commercial activities than educational or cultural projects. In comparison the experimental nature, the low costs and an extreme scalability make an open source technology such as OpenSimulator particularly feasible for doing research in the field of cyber archaeology and cultural communication.

2. 3DMETAVERSITY

2.1 Introduction to 3DMetaversity Project

3DMetaversity is a research project conceived and led by Davide Borra, during his PhD activity (2007-2010) at Turin Polytechnic. *3DMetaversity* plays the role of conceptual and technological infrastructure for our virtual archaeology initiative about *Interamnia*. Technically speaking, *3DMetaversity* is an independent OpenSimulator grid dedicated to academic experimentation on *metaverses* (Borra, 2010). All the disciplines dealing with the concept of space, such as architecture, landscape studies, design and archaeology can take advantage of this online virtual environment system (fig. 3).

Figure 3: Collaborative modelling session in *3DMetaversity*

At start-up phase *3DMetaversity* involves an international team of academic institutions such as Faculty of Architecture of Turin Polytechnic (Italy), University of California Merced (USA), Faculty of Architecture of the University Gabriele d'Annunzio of Chieti (Italy), Lund University (Sweden) and NABA, *Nuova Accademia di Belle Arti di Milano* (Italy). Researchers and students from all these academic institutions have tested many different ways of building architectonic shapes, designing spaces and developing methods of interaction between users and contents. Technical support and server hosting facilities were provided by the Italian Supercomputing Centre, CINECA. Thanks to this partnership a totally free

participation to the start-up phase was guaranteed. This was particularly convenient for a research project aimed at the evaluation of Web 2.0 and open source technologies. The main goal of *3DMetaversity* is, in fact, developing an exchange framework for academic knowledge about 3D graphics, collaborative environments and online virtual worlds. Thus, all materials created in this open platform follow an open source philosophy for academic purposes, with the condition of acknowledgement and citation of the authors. The website of the *3DMetaversity* initiative is:
<http://www.3dmetaversity.org/>

2.2 Collaborative Virtual Reconstruction

Taking full advantage of OpenSim server technology, available through *3DMetaversity*, we created a multi-user virtual environment aimed at the simulation of significant monuments of the Roman Teramo. Despite the experimental nature of *3DMetaversity* platform, the design activity of our *cultural metaverse* and its epistemological modelling are, already, at an advanced stage. We started to develop our virtual archaeology project coupling the interpretative process of the archaeological sites to a precise definition of the learning and communication purposes we pursue (Forte, Bonini, 2008). In this way we did not carry on a philological reconstruction of the archaeological sites, but, otherwise, we chose to deconstruct the historical context of *Interamnia* through the implementation of an extensive reconstruction of its most important and documented monuments in the *cultural metaverse*. Thus, the area of our grid becomes an augmented space where media contents such as video, graphics and images become ideal components for defining a sustainable project of *musealization* within the monuments themselves. We refer to places that actually are not suitable to receive massive flows of visitors and tourists and are not very well known. The Roman Theatre, for example is only partially excavated, while the remains of the *Domus of Lions,* with its delightful mosaics, is located into the basement of a private building. At the same time, we conceive our reconstructed archaeological sites as an ideal context able to host forthcoming educational activities and cultural events. Thanks to the great availability of interactive and narrative spaces within our *metaverse,* these cultural processes will, soon, become feasible. Educational experiments that we have already planned, but not implemented yet, are the interactive activities that will be probably located inside the Roman Theatre (fig.4).

Figure 4: The Roman Theatre of *Interamnia*

For example, we hypothesize a collaborative virtual reconstruction of the *frons scaene* performed by a group of students/users on the basis of pre-modelled architectonic elements and information given by the archaeologists (a 3D repository). Another collaborative activity in our *cultural metaverse* might be the setting up of real-time dramaturgical plays in which users, embodied in avatars, will co-star with autonomous agents on the scene of the Roman Theatre. The modelling activity accomplished in our project is based on the usage of parameterized primitives (prims) that can be created and edited by the in-world building panel of OpenSim viewer. If compared to other 3d modelling systems, such as 3D Studio Max, this type of simulation does not allow modellers to obtain a high level of precision or high quality models (Galeazzi, 2007), but permits the sharing of data and information between users. We don't consider such technical restriction as a limitation for our project, but as an opportunity to test new forms of collaborative virtual reconstructions/simulations.
One of the key features of our *cultural metaverse* is a multi-users platform for archaeological simulation. This means that several users can perform, simultaneously, a set of complex tasks by their avatars. For example they can take part in a collaborative session of 3D modelling or participate to collaborative creation of in-world contents. The avatar-based simulation, which we used in our project, implies another important consequence. Virtual space experience is enriched by the perception of the real proportions between monuments and human body. We think these features are extremely interesting for promoting educational activities for students or training sessions for 3D modellers within the simulated archaeological environment itself. More specifically, in our island, we have reconstructed the Roman Theatre and a *Domus.* Such 3D models are built on scientific databases obtained by analyzing and comparing historical data and archaeological surveys.

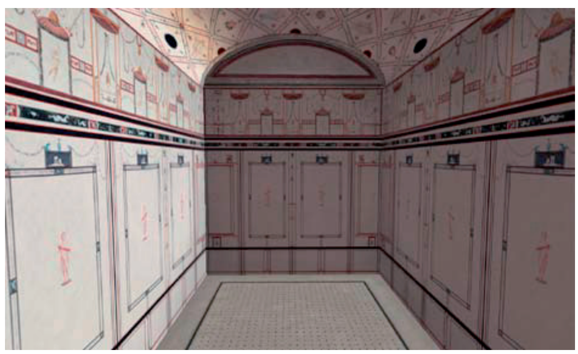

Figure 5: The central room of the *Domus*

The Roman *Domus* was discovered underneath the early church of Saint Mary *Aprutiensis* and it is still partially covered by this monument. Thanks to material evidences, the *Domus* can be dated between the 1st century BC and the 2nd AD. During the archaeological excavations, archaeologists rediscovered just some parts of the *Domus* such as the *peristilium* and three rooms located along its west side. The rectangular *peristilium* is characterized by walls in *opus incertum*, and columns of bricks painted in red and white. The *impluvium*, paved of *opus spicatum*, is not located, as usual, at the exact centre of the *peristilium*. The central room is bigger than the others and has a typical floor in white and black mosaic. Its walls, made in *opus incertum*, are decorated with geometric motives and stylized vegetal elements on a white background (fig.5). The southern room was partially reused as foundation of the cathedral. It is paved in *opus testaceum* with a random use of white mosaic *tesserae*. Geometric motives in yellow and ochre are still recognizable. The northern room is only accessible from the corridor of the *peristilium*; it is paved in *opus testaceum* and displays a mosaic in geometric motives. The walls are painted over a red background with geometric and vegetal elements. The well known use of regular and standardized ornamental schemes in the Augustan Age architecture (1st century BC – 1st century AD) was used as documentation for the 3D reconstruction of the *Domus*. The second monument, studied and reconstructed in the *cultural metaverse* was the Roman Theatre (fig.4). It was built at the beginning of the Augustan Age and firstly excavated by the archaeologist Francesco Savini at the beginning of 1900s. Since the Theatre had been incorporated into later building, in 1926 it was the object of a more scientific process of excavation and restoration (Cardellini, Montani, 1934). The last archaeological survey of the site, during the 1980s, unearthed the remains of almost the whole order of arches that constituted the external bottom part of the *cavea.* A small section of the *scaena* was excavated and restored as well.

The Roman Theatre of Teramo was a medium-size scenic building able to accommodate about 3000 spectators. The *78* meters in diameter *cavea* was held up by a structure of 21 radial walls in *opus incertum*. They culminated in a semi-circular order of 24 pillars and 23 arches made in local stone or travertine. The external facade was probably constituted of two overlapping orders of arches in travertine. Remains of the *orchestra* were found along the internal edge of the *cavea,* in the form of paving slabs of travertine. These last ones are characterized by the presence of small canals that perhaps were built to support a fence*.* A magnificent *scaena*, decorated with marble columns, statues and architectonic elements enriched the building as well. Due to a very few archaeological evidences about the *scaena*, we did not reconstruct this part of the building, communicating in 3D just a general idea of its volume and shape (fig 6).

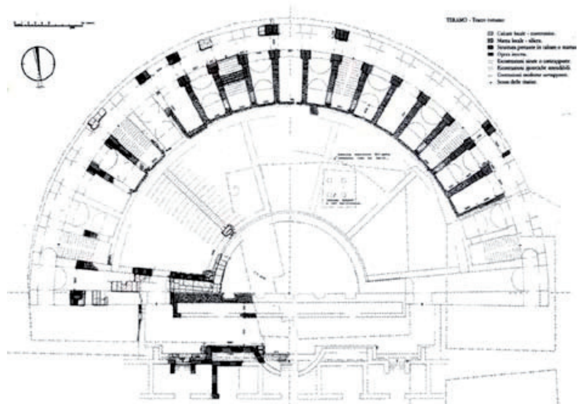

Figure 6: Archaeological map of the Roman Theatre

In the reconstruction process we experienced that the OpenSim platform, makes the virtual simulation more flexible than in SL with less restrictions in modelling and texturing. The main difference is about the size of *prims* that can be used inside the grid. If in SL they cannot exceed 10x10x10 meters, in OpenSim they can be much bigger (mega prims), depending on the server configuration. Especially in architectonic modelling, this limitation of SL forces modellers to perform the same action several times in order to create the structure of a big building. Texturing in OpenSim is much more flexible and easy because modellers can use a massive upload of free textures, differently from what occurs in SL. Having a high amount of *colormaps* and being able to test them, many times, on the 3d models led us to obtain good results, particularly in the simulation of the *Domus*.

Another important difference between SL and OpenSim is actually not connected to the technological aspect but to the social-communicative one. The number of registered SL users has reached 18 millions in January 2010. Even if these numbers not correspond to effective active users, the amount is really impressive. We cannot say the same for OpenSim since it is not yet a social phenomenon and also in our case we expect to manage a limited number of users, at least in the first phase of development. To enhance the socio-cultural experience of our grid we decided to create a specific interactive space dedicated to the *musealization* of archaeological sites using the metaphor of a virtual library.

It is called *Virtuoteca* and can be defined as an open space where users can learn about monuments and sites in a collaborative way (fig.7).

Figure 7: The *Virtuoteca*

At the first floor of this virtual place visitors can find information about the urban context, the territory and the lanscape. In the same place they can also explore the map of the current city of Teramo compared to the urban structure of *Interamnia*. Posters and multimedia contents about the early Roman city are displayed as well. This hyperspace can be considered a meta-museum where visitors can have a pre-experience and/or a post-experience in comparison and in relation with their real visit into the archaeological museum or around the city.

3. CONCLUSIONS

At this stage of the research, still in a prototypal phase, it is quite difficult to figure out the impact of this experiment at educational and social level. The involvement of the archaeological museum and of an educational program for the schools (especially elementary and high schools), is a promising starting point for the use of the virtual island in OpenSim. In addition it is necessary to study also mechanisms of involvements and interaction with the citizens of Teramo and, in the future, tourists and visitors. In this case it will be important to study specific educational forms of social communication in the cyber space. The virtual performance of an ancient drama in the Roman theatre, the creation of specific archaeological graphic libraries for the Roman architecture (for example playing how to assemble or disassemble monuments and sites) could increase the *edutaiment* within the island and the collaborative participation of groups of virtual visitors, possibly with the assistance of an instructor (strongly recommended in the case of schools and students). We will develop also a space where registered users (again principally students) could upload digital contents coming from their experience of visit in the city.

Short movies, pictures, texts, comments will create a 3D blog for students and teachers.
The implementation of OpenSim-*3DMetaversity* for the archaeological museum of Teramo involves also a stereo display, thanks to the availability of a stereo viewer. In that way the experience of the museum visitors will be enriched by an additional immersive experience in *3DMetaversity*.
The virtual island of Teramo will be a place where to develop educational activities involving students and teachers from different backgrounds. A typical scenario could be constituted by a teacher with a class bringing his/her students to the virtual museum in OpenSim and planning an interactive seminar with them and other visitors. All of them will attend the meeting as avatars, visiting the sites, the exhibitions and interacting with 3D data and models. These activities will be totally interactive increasing the sense of embodiment involving the avatars in several different dynamic behaviours, chatting, discussing and exchanging information.

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The project "Teramo: a city virtually dressed" is supported by the City of Teramo and the Institute of Technologies Applied to Cultural Heritage (CNR, Rome). Special thanks are due to the Director of the Archaeological Museum, Dr. Paola Di Felice and to all the Italian CNR colleagues of the Virtual Heritage Lab-ITABC. The key concept of the entire project communication was developed by Maurizio Forte (UC Merced, United States) and Eva Pietroni (CNR-ITABC, Italy).

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RELIVING THE PAST: 3D MODELS, VIRTUAL REALITY AND GAME ENGINES AS TOOLS FOR ARCHAEOLOGICAL RECONSTRUCTION. THE CASE STUDY OF THE ROMAN *VILLA* OF FREIRIA

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KEY WORDS: 3D Model; Virtual Scenarios; Recreation of Social, Urban and Architectural Environments; Visualization and Use of a Recreated Space.

ABSTRACT:

Virtual Reality (VR) is a device for object visualization, whether past, present or future, when its access is denied for some reason. Applied to archaeology, VR allows the recreation of disappeared sites and environments, which otherwise would not be possible to access.
The success of early tests performed on historical objects motivated the development of research projects in buildings with architectural value, where resources are available to carry out an integrated investigation work of automatic survey and modelling.
However, most of the archaeological field work has its own restrictions, reflecting on the campaigns characterized by exhaustive excavations made in a short period of time, and buried at the end as a way to preserve the architectural structures. In these cases, where it is not possible to have resources in order to conduct a large-scale campaign, it is necessary to manipulate previous records and data as a basis for building a virtual model.
In the present paper, we intend to present a methodology for the virtual reconstruction of objects and sites, when it is only possible to obtain previously collected information, in accordance with the distinct archaeological onsite campaigns, and where data has the quality to this type of implementation. To achieve this purpose, the case study of Freiria, a rural *villa* of the Roman period, is described as an exemplification of the process. Finally, we discuss the results.

1. INTRODUCTION

Anyone who has previously participated in an archaeological campaign knows that the site rarely includes a clearly defined 3D component. A space is usually read two-dimensionally, with no visual correspondence with the theories it presents. Furthermore, physical rebuilding is nearly impossible, partly due to the costs, but mainly because there are numerous hypotheses on what a given space could have been or could have looked like.
For this reason, the use of 3D modelling and Virtual Reality (VR) software (and, of course, hardware with good performance) is highly appropriate to rebuild a site in a way that allows several hypotheses to be experienced on a human scale. In addition, if all the procedures are meticulously recorded, it is expected to get a basic tool that might be used in other researches, i.e., to implement the potential use of this type of software as a support tool for archaeological investigation.
In recent years, newly implemented archaeological survey equipments have allowed more precision and speed in recording and acquiring structure-related data, such as 3D scanners, that create a cloud of points to be manipulated by software, which generates a mesh of the scanned object to apply the texture.
However, there was no capacity to implement a project of this nature in the archaeological sites that were subject to traditional research methods of excavation, survey and packaging, by burial the structures; the alternative is to use data obtained by traditional surveying methods. With these elements it is possible to construct a highly complex model to satisfy the scientific demands (Nogueira, 2005) but extremely hard to manipulate in real time, due to the increase of associated information. In order to overcome this inconvenience, there are several ways, from splitting the model into different but associated files to geometry simplification.
Low cost representations, such as Virtual Models and Game Engines software, are excellent divulgation tools (Koutsoudis *et al.*, 2008), when the main objective is to visualise non real world (and therefore virtual), since they allow, by importing 3D models created in others software, the customization of scenarios. But its implementation implies to recognize the potential of the edition tool, to get to know what to expect, in terms of physical performance and ambiance. Basically they are data simplifications that enable real-time manipulations; feature to use if the reduction of this information is prevented from threatening the history told by the model.
Information on virtual rebuilding may be distributed and shared on wiki sites (The Elder Scrolls Construction Set Wiki), by researchers in the same thematic area (Kimer *et al.*, 2001), and promoting faster results and more discussed conclusions. This way, the models are created while the investigation is being carried out and the results can be seen on site, during the field works (Web3D Consortium, 2006). Another potential application of these types of simplified models is the Internet, as a mean of sharing information while consumers require it to be more and more a complete interactive experience (Hartman & Wernecke, 1996). But instruments to allow this impact are needed, and models should be adapted to correspond to using needs.
The use of a game engine to create the scene, ensuring the graphical quality and the environmental tools (Artificial Intelligence - AI, physics, vegetation, weather conditions), along with a very natural and user-friendly map editing software, was definitely the right choice, and allowed the

achievement of the initial goals of this work. The experience of visiting this virtual scene gives a far greater sense of involvement than commercial virtual reality software would provide, while offering the possibility of adapting the software for more specific uses (Champion, 2004) such as establishing a population of virtual users which might lead to estimations on the extent of the farm (Gutierrez *et al.*, 2005) – a theme much overlooked nowadays – and definitely contributes to a new way to discover history.
We expect that this technology becomes available in the near future in a fully commercial version – or in Open Source (OpenGL®), or in 3D Open Platform (Slusallek *et al.*, 2009).
The aim of this research project was to reconstruct not only the buildings but mainly the ambiance of the site at the time it was used and provide technical discussion among peers.

1.1 The case study

The roman villa of Freiria (38º43'15.76''N 9º19'23.08''W) is located in São Domingos de Rana, Cascais (Portugal), on the shoulder of one of the many valleys near the village of Outeiro de Polima.

Figure 1: Freiria complex: 1 – Domus – manor house – constructed around a central courtyard; Infrastructures needed for daily life, and these were arranged around a second courtyard and consisted of: 2 – Storehouses/press, outbuildings related to farm work; 3 – Houses and servants quarters (cells); 4 – Baths; and, 5 – Granary.

Discovered in 1980 by Guilherme Cardoso, only in 1985 was it starting to be intensively studied on the initiative of archaeologists (Cardoso & d'Encarnação, 1993), that continue to investigated this site until 2002. Field works revealed the existence of a building complex (Fig. 1) consisting of a master's home surrounding by structures appropriated to agricultural production, with occupation from the 1st century AD to 4th century AD.
However, for reasons of personal availability from the research team, it was necessary to limit the field work to August (school holidays), which reduces the apparent long period of research to about one and half year of effective field work. That compelled us to reconsider the whole strategy of full excavation of the site.
Thus, the digs were completed by systematic surveys – photographic, graphic and cartographic – in order to integrate all the data at the same database, before they are properly covered with gravel over geotextile fabric, the way to protect and preserve the structures. This means that in all of these years, it was never been possible to observe at once, the whole site.

1.2 Data Gathering

Thus, for the modelling work it was possible to collect three types of data:

1 Photographic survey;
2 Topographic survey; and
3 Archaeological survey.

The photographic survey consists of a collection of images that report the work executed during excavation and prospecting by archaeologist Guilherme Cardoso; there were also some aerial photographs, provided by the Air Force (FAP-BA1, 1995) or taken during private flights over the area. The photos are extremely useful for a work of this nature, as they provide all the detailed information for the model that cannot be observed in any of the other surveys, such as geometry, location and texture. This allows a later adaptation of the model to the site particularities.
The topographic survey consists of two different surveys, one based on military maps at the 1:25,000 scale (IGEoE, 1992) covering a larger area but less detailed, and the other performed by the City Hall Services, of a smaller but more detailed area at the sca1e 1:1,000 (CMC, 1975).
The archaeological survey consisted of two separate files. The first is a less detailed map contained all the structures, including walls and pavement, and their possible use. The second consisted on a planimetric and an altimetric survey of the site mapped at 1:20 scale on graph paper, with a great detail on element and object's characteristics.

1.3 2D Base Elements

All data was compiled into a single file which contained the following layers (Fig. 2):

1 Topographic survey;
2 Archaeological Survey (planimetric and altimetric), with detailed 1:20 information (stone by stone);
3 Archaeological Survey (structural) with general 1:100 information on the position of the various walls (specifically carried out for that purpose by a topographer);
4 Archaeological Survey (non-structural) with a variety of information such as different types of pavement and the aqueduct location (specially arranged by the architect J. A. Bicho for the urban plan of the surrounding area);
5 Excerpt from the 2x2 meter grid that was used in the survey and the field work.

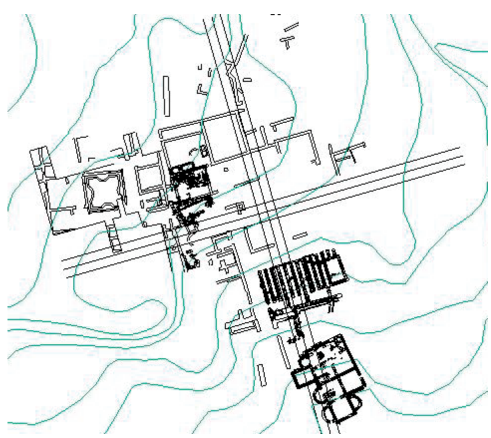

Figure 2: Example of the performed layers

With all the information that usually is related to the traditional field work properly compiled in the same file, the next step was to import it into the 3D modelling software.

2. 3D MODELLING

Considering different rebuilding hypotheses it was decided that the 3D model would represent, in distinct layers, its current state and the diverse theories on past uses.

2.1 Modelling the Present

The terrain was the first object to be model; the objective was to create a mesh that would accurately simulate the real terrain and allow the easy placing of any object, independently on being dug up already. For this reason it was chosen to, somehow, replicate the grid used during the excavations.
A first stage of the terrain model was created with the Terrain tool of 3ds Max (Autodesk™2008)[*]. The result was a highly detailed but complex Triangular Irregular Network – TIN. After this, a second model was produced, consisting of a large plane divided into 2x2 meter squares (Russo, 2005). This mesh was then applied to the terrain model, using the Conform tool, which matches the height of the several vertices that define two surfaces in order to fit each another. The result was a terrain mesh simulating the original, but consisting on geometric figures that matched the size and location of the original grid (Fig. 3).

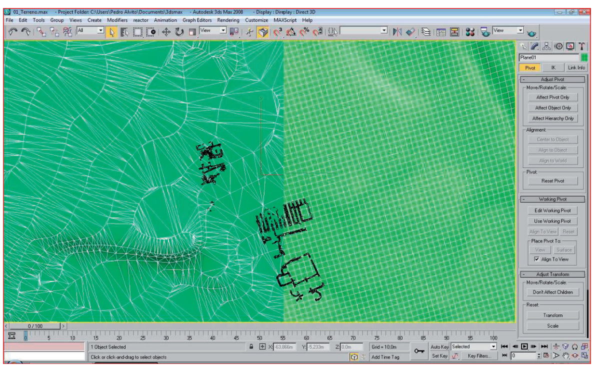

Figure 3: Conversion of the topographic survey in geometry, and adjustment to the 2x2 m grid

The model for the visible walls in the site is made up of two types of geometry and originates from the two surveys available.
The altimetric archaeological survey consisted of several closed polylines, each at a different height, representing the top stones of the walls. As assigning to each stone its correct height would be very inaccurate and a time-consuming task, the same generic height of -10 cm was assigned to all the stones.
Once the stones were modelled, the structural generic survey was used to create the configuration of the wall, subdividing and extruding solids to fit the height created by the stones.
At this point some adjustments to the terrain mesh were necessary to compensate for excavated terrain that had not been taken into account in the topographic survey (Fig. 4).

[*] 3ds Max (Autodesk™2008) software was chosen not only because it was accessible at the time and required no extra training time but also for being compatible with the extension of drawing files used in the AutoCAD (Autodesk™) software.

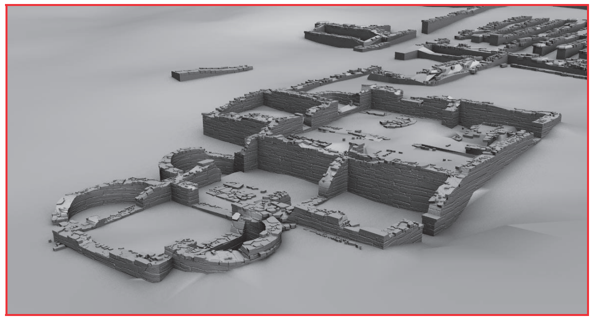

Figure 4: Reconstruction of today's Freiria Buildings

2.2 Rebuilding the Past

As an example for the rebuilding process that this paper describes, and given the time frame, it was decided to focus the work on the granary. The granary is now the centrepiece in the villa, and the building for which archaeologists have come up with the best theories.
Previous survey work led to realise that this structure had been modified during its occupation. This may have been unnoticed if automatic survey had been used (Fig. 5).
To the original 123 m^2 granary area, 35m^2 were added as verified by the enlargement on the foundation wall, which is visible on the plan. These values can also be used to estimate the size of the farm.

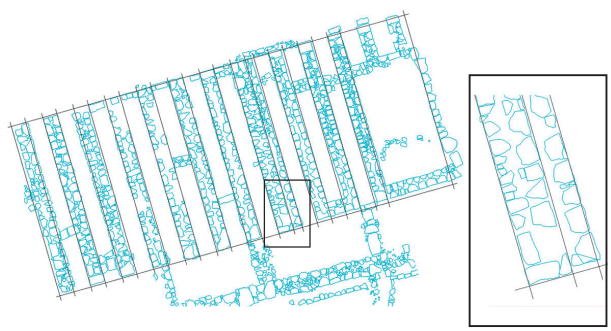

Figure 5: Plan of the foundations walls from the granary, with detail of the enlargement

The offset of the foundation walls, executed to enable ventilation, is missing in the eastern zone of the building. There, the terrain is higher, which led us to suppose that was the side where the entrance of the granary was located.
And since no evidence of tile or masonry was found on the field, we assume that the walls and the roof were made with perishable materials.
For the structure, the last moment of use was chosen to be represented.
The modelling work began with the acquisition of information on the theories from responsible archaeologists and the analysis of existing bibliographic data (Alarcão, 1985; Macaulay, 1978). This enabled the definition of which theories would be represented and tested with this model. The investigation so far has revealed that the granary had a wood structure, with a thatched roof and walls (Bédoyère, 1991).
The model followed the normal construction stages, beginning with the stone foundations which are still in place today (Rua, 1998). On top of the foundations is a sub-structure made of

wooden beams which supports both the main wooden structure and the floor.
This structure is made up of a series of porches that also defined the angle for the roof. The structure is aligned with the stone foundation.
Side and back walls are covered in thatch, modelled to hang from a series of horizontal wooden beams that run along the porches. Only the front wall, where the entrance to the granary is located, was made of wood.

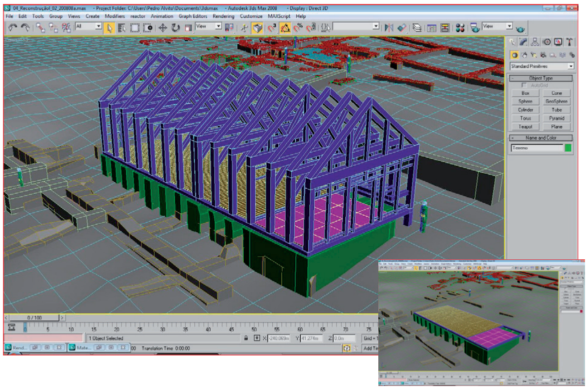

Figure 6: Stages of the Freiria's granary reconstruction, based on the existing walls

Modelling of the roof began with the creation of support beams that connect to the porches, and several layers of thatch where then modelled on top. To complete the model a series of inner shelving units were created, along with the access stairs, the wooden and stone pavement and the ventilation grid in the granary annex. The access stairs are essential given that these granaries were built on an elevated plane for ventilation.
The final shape of the granary is still open to several different theories as we have no indication of its correct height, and the interior might have taken various forms, so this model still needs to be evaluated and compared with several variations (Fig. 6)

2.3 Post-Modelling Treatment

After the modelling stage, and before the model is imported into the game engine, it needs to be textured. This adds realism to the scene by showing the different materials the granary is made from (Adobe® Photoshop® 7.0).
Texturing is a 2-step process: the application of the different textures on bump maps, and then the scaling and correct positioning using a UVW map.

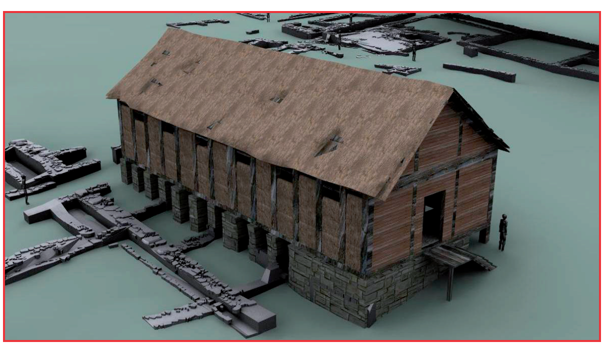

Figure 7: Texturing Freiria's Granary model

Each texture is composed of a texture map and the corresponding bump map. Each map represents a different material which works with this method. As each object represents only one material the creation of more complex textures was not required (Fig. 7).
This stage of the work allowed the researchers the first idealisation on the building appearance and its volumetric expression in contrast with the horizontality of the archaeological site.
However, the model is not dynamic, i.e., any change either in its creation or in its visualisation – such as a new view point – involves a complex and long rendering process, with no prediction of what will be the outcome.

3. INTERACTING WITH THE MODEL

The virtual reality model was then created using the map editor of a common commercial computer game (Bethesda Softworks®), to allow manipulating entities. The game runs on the Gamebyro game engine, which has a quality graphic engine, as well as physical realism and an AI engine. The software is also bundled with a vegetation program to create trees and bushes.
One more advantage of this kind of procedure – personalization of a game engine (Grand & Yarusso, 2004) for scientific visualization (Bianchini *et al.*, 2006) – and particularly of this software, is the creation of AI-driven avatars. The program already has a large list of editable AI scripts to manage moving scheduling of actions and interaction, to implement in subsequent phases of the project.
The model is visualized through the game itself (Bastos *et al.*, 2006), since the scene is loaded as a custom map. Inside the game, our avatar can move and look around freely by using a free-look camera and a combination of keyboard and mouse moves common in first-person games.
Additional commands are possible, namely extra movements, such as free-camera, toggle collisions, and changes in the weather conditions (Fig. 8).

Figure 8: Interaction with the virtual space

The manipulations of this model allowed comparisons and discussions about the archaeological site, in an interactive environment, according to the theories of each specialist and evaluating results in real time. For instance, note the entrance of the granary, which despite consensus about the chosen area is not so consensual in terms of configuration. Namely, it could be placed by taking further advantage of the terrain slope if it was located near the corner of the north facade; or if it was an entrance for farm carts; or both (Fig. 9).

Whatever has been true, it was only possible to consider all these hypotheses after visualizing and experiment the place.

Figure 9: Models representing the evolution of granary reconstruction, and detail of still unsolved piece of structure

4. DISCUSSION AND CONCLUSION

In archaeology uncertainty is certain. For this reason, field work implies scientific procedures that compel to intensive register independently from what could seem to be the findings' irrelevance. Therefore this has been the methodology followed by the experts since they started their works in Freiria in 1985.
Although, the long period that is been study, Freiria's excavation only took place in a month by year and all the digs are systematic and carefully covered after each campaign, as it happens in all the archaeological sites. For this reason, automated processes of data acquisition could not be implemented and it was necessary to use the available 2D data, with high accuracy surveying. This procedure applies also to archaeological sites that have been suffered subsequent degradations and where the only remains are the traditional drawings.
Likewise, the model intends to draw the line and make clear the differentiation between reality and theory, given that archaeological structures integrate the terrain surface; then, based on the existing structure, the granary was literally built up with wood beams and slats dressed with culms, with a constant discussion of technical aspects.
Starting the project with the building that initially might have seemed to be the most consensual, it doesn't mean that the represented model entirely satisfies all the technicians and corresponds to every detected phenomenon in the structures, namely in terms of accessibility. In the meantime, the way information was gathered supports changes to the model, providing experimentation and discussion among the community.
We prove that these hypotheses or speculations, very often represented in a 2D sketch or blueprint, are far more useful if presented and used in 3D models. It is the quickest way to put and to test an idea, mostly because it is easier to articulate and to upgrade an idea about an object once we can see it. 3D models are currently the ideal way to convey information about an object, a city or a whole civilization.
In the end, it cannot be claimed that the thesis answered all the questions and eliminated all doubts. It allowed, however, the team of archaeologists to try their theories in a completely new way, and it did manage to raise some important issues that would otherwise have been overlooked if the space had never been seen in a fully three-dimensional way.
Most of all, this ongoing research work allowed us to relive the past.

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3D CULTURE DATABASE CARNUNTUM

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KEY WORDS: Project Paper, Databases, Carnuntum, Ammaia, 3d-Databases, 3d Laser-scanning, 3d model Data-reduction

ABSTRACT:

The new 3d Database of Carnuntum/Austria is presenting a large variety of finds from the region of Carnuntum /Bad Deutsch-Altenburg/ Austria via internet, allowing the user to view the selected objects in different 2d and 3d formats. One of the tasks was to prepare the laser-scanned objects for the internet and therefore reduce their file size to approximately 1% of its original size while maintaining the visual information. To evaluate these techniques on other sites and objects, this procedure will be used to prepare a database at the site of Ammaia in Portugal. More than two million archaeological finds – most of them not yet scientifically examined – are stored in Lower Austria's archaeological collection. New discoveries are being added all the time through the annual excavations that take place within the archaeological park. The artifacts are kept in the storage of the Kulturfabrik Hainburg and is closed to the public. Only a small fraction of the excavated objects can be presented to a wider public in exhibitions. In order to enable interested lay-persons and specialists uncomplicated access to the archaeological finds, various approaches were discussed. Finally the decision was reached that apart from attribute data the geometrical properties and a model of the find as realistic as a photo would also be provided for the user. At first about 1,500 of the most important objects were processed, showing a broad cross-section of the archaeological park's inventory. Subsequently it is planned to process 2,000 objects annually. There are no plans to create a complete record of the whole inventory.

1. INTRODUCTION

More than two million archaeological artifacts – most of them not yet scientifically processed – are stored in Lower Austria's Archaeological Collection of Carnuntum. New items are being added each year by the ongoing excavations taking place within the Carnuntum Archaeological Park. The artefacts are kept in the archive of the Kulturfabrik Hainburg which is closed to the public. Due to lack of museal facilities and space only a small fraction of the excavated objects can be presented to a wider audience in exhibitions. It is also important to note, that while some of the archeological items as single objects cannot be regarded as exceptional discoveries, and therefore it is not necessary to exhibit them all in museums, as an "ensemble of artifacts" they represent a high value. However, to easily access ensembles of archeological finds new and different approaches have to be developed. The concept of museal exhibitions is mainly suited for single objects or assemblages of a few similar artefacts. Due to research being carried out in museum archives it is difficult and laborious for researchers and museum personal alike to remove, study and to put back a large numbers of items. Because of these reasons a method was conceived, which allows the access to a virtual 3d replica of the object, to high-quality photographs and to textual metadata (description of the item, location and date of excavation, etc.) via the internet. The main advantages of the system are the possibility to access content from everywhere where internet is available, to be able to work with high quality object photographs and as main innovative feature the possibility of examining the 3d object from any user-defined angle and position (with a range of magnifications available) in a 3d flash-based viewer.

Figure 1: Flash driven 3d Viewer

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Thus a researcher can conduct a study on a wide range of items in a quality and a way equaling in many aspects the information content of an on-site study in the museum archives. Measurements and comparisons can be made faster and easier and on every part and surface point of the scaled object, as the high-resolution 3d model can be also accessed. This is an essential advantage compared to conventional 2d representations (like plans and drawings) which at best allow measurements from fixed angles or positions. Even if it is later on necessary to study items on-site, a precise pre-selection via the internet-database can be made. Supposedly for many investigations the information provided on the internet is already sufficient, especially as registered users are allowed to download 3d object models in a much higher resolution than the resolution of the internet-viewer. For the wider public the database can be regarded as a kind of "virtual museum", where the objects are presented in a very appealing way. Thus the database is able to serve two different user groups: on the one hand the needs of the scientific community, on the other hand it is a representation of cultural heritage towards culturally interested lay visitors. In a first step about 1,500 of the most important objects were processed, showing a broad cross-section of the Archaeological Park's inventory. Subsequently it is planned to process 2,000 objects annually.

2. DATA AQUISITION AND CREATION OF THE HIGH RESOLUTION MODEL

The main innovation of the project and therefore also the main technical task to solve was the development of a quick and uncomplicated workflow from the capturing of the geometrical properties of an object to the transformation of this data to an appropriately presentable form suited for the internet. The geometrical data was collected by a laser-scanner with sub-millimetre geometrical accuracy. The high resolution was needed to produce an appropriately precise virtual replica of the item, which shows not only the main form but also delicate detail or marks of production and the wear and use on an objects surface. It is this detail information which makes the data invaluable for scientific study and is a requirement if the virtual presentation is intended to have similar information content as the original object. As a large number of objects have to be recorded, not only the high resolution of the scanner but also the easy usability and quick handling during the scanning process was important. Also a fast workflow had to be established to transform the raw data into the high-resolution 3d-model. The next step in data aquisition involves taking digital photos. Here not only representative images are taken of the item, but also a complete set of photographs suitable for semi-automatized photogrammetric measurement. From this set of photographs a second geometric model is created, which is textured with colour information taken from the object´s surface. The scanner provides only geometrical data, so that surface colours have to be taken from the photogrammetrical model. This model is also an important helper during the geometry reduction process. Scans and data acquisition are conducted by the Department of Survey and Geo information of the Lower Austrian Government.

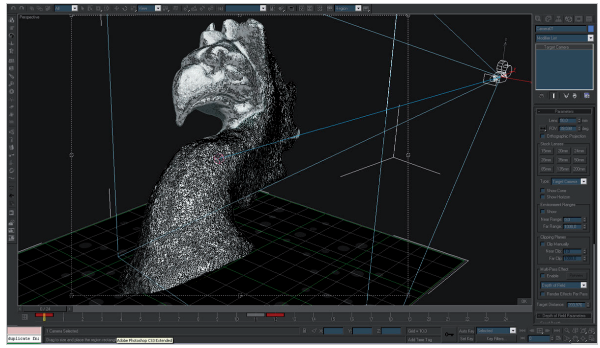

Figure 2: Reduction and Surface reconstruction

3. DATA PROCESSING AND INCORPORATION INTO THE DATABASE

The high-resolution geometric model has to be processed in a way that it is suited for presentation via internet. This means the reduction of overall data to a small percentage without losing characteristic surface features. This can be achieved in two ways: one is the "smart" reduction of geometry – meaning that on uniform areas the number of polygons is decreased substantially. This is nothing exceptional and can be carried out by most programs capable of working with 3d data. However, to be able to generate 3d objects with finely detailed surfaces and very small geometry, a second step is required: Detailed surface geometry of the high-resolution model is incorporated through a special procedure into surface texture (colour information) and projected onto a similar, albeit reduced resolution geometric model of the same object. This means that shallow scratches, indentations, incisions are no longer present as geometry, but recognisable only as textural colour information on a low-polygonal model of the artefact. Visual experience on the user side loses almost no quality, as all information is still retained, but data size is reduced to a fraction of the original. Most objects appear due to this workflow in the 3d-viewer shaded in neutral grey material, which helps a better recognisability of surface topography. Only a few objects have been provided with specially textured surfaces, which do also posses the original colours of the surface taken from the photogrammetric survey`s photographs. The workflow of this second type of presentation is much more time-consuming and therefore used only in case of some particular items. Processing of 3d data is the task of specialists at 7reasons company. As the archaeological collection's items have been excavated during different periods (within the overall time span of over a century or so), there is also lack of consistent filing and classification. The database project understands itself as a step in the direction of a standardised and unified archive of these artefacts by defining main sets of categories and characteristics. These object properties are used as the main query arguments (description, material, date of excavation, estimated chronological date, found in context with, archive place, condition (state) of object, location of excavation, object size, catalogue number). The database is SQL-based and hosted on a security-server of the Lower Austrian government.

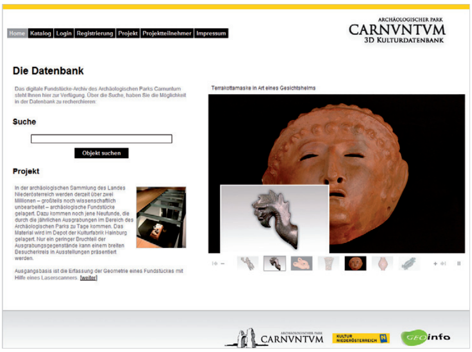

Figure 3: Frontpage

4. USER INTERFACE AND DATA ACCESS

The user Interface consists of a homepage, where the arriving visitor is presented with general information on the project, and also one randomly chosen object of the database. Also a selection of other objects are shown in small preview pictures. The aim is to create an appealing presentation for all visitors right away and to show some of the features of the database as an invitation for further search and use. For scientific users there is a login option, after which they can conduct detailed queries, bookmark and choose objects for download. The "Catalogue" page offers a wide range of possibilities for search according to the main set of object characteristics or a query utilising parts and keywords of the description texts. A large advantage of the user interface containing flash embedded 3d object presentations is, that it was executed in a way, that it is suited as a platform independent application, which means that it can be also displayed on handhelds, mobile devices and so forth.

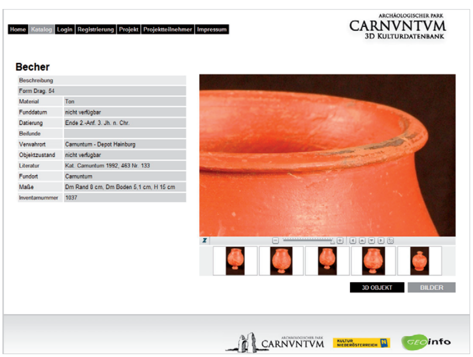

Figure 4: Zoom-Picture View

5. APPLICATION IN AMMAIA

It is also planned to establish a similar database in the excavation area of Ammaia, Portugal. This project will be also an evaluation of the usability and applicability of the so far developed database structure in different, more difficult conditions. Here no high-resolution scanner was available, so an alternative, cheaper solution had to be found. The workflow will be established using an open source scanning software, which applies a camera and calibration sheets and a hand-guided-laser scanning procedure.

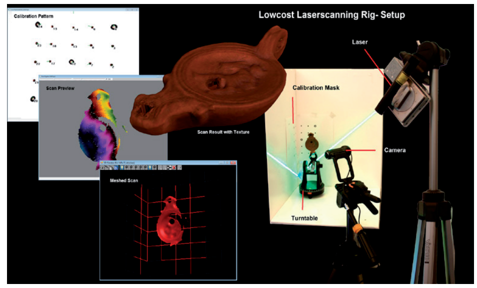

Figure 5: Setup of the David Laserscanner

6. FURTHER DEVELOPMENT PERSPECTIVES (OBJECT INFORMATION SYSTEM OIS)

For the near future several developments are planned for subsequent database systems according to experiences made with the Carnuntum and Ammaia approaches. One very important aspect is the incorporation of data linked to object parts or surface details. We would like to term this approach "3d-OIS" – an object oriented information system – images, textual information, etc can be incorporated and displayed linked to detail areas and topographical features of certain objects, much alike a GIS system displaying information linked to geographical regions. Databases applying these features could contain beside archaeological artefacts also virtual reconstructions, where the hypothetical part is marked in different colour or texture and supplemented by links and information placed on the objects surface. This 3d-OIS system would be developed in Unity, a platform independent 3d engine. This engine can be functionally expanded by scripted behaviours and functions based on Java, C and CS programming languages.

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MULTIMEDIA COMMUNICATION OF CULTURAL HERITAGE: THE EXPERIENCE OF DARDUS DEPARTMENT IN THE POLYTECHNIC UNIVERSITY OF MARCHE

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KEY WORDS: Multimedia, Cultural Heritage, Web-Communication, Virtual Reality, Virtual Reconstruction, Virtual Exhibition

ABSTRACT:

For several years architectural representation has been increasingly relying on the use of new digital instruments and the DARDUS Department (Department of Architecture, Survey, Restoration, Drawing, Urban Planning and History of the Polytechnic University of the Marche region) has carried out important research concerning the use of Information Technology as a tool for architectural analysis and communication. Using methods for the quick documentation of historical sites, the Dardus staff developed three main types of digital tool: Virtual Exhibitions; Modelling and Virtual Tours; Multimedia Tools for Historical Sites. The paper presents three case-studies and explains the methods and technological issues linked with the process of documenting cultural heritage. The following cases are presented: The virtual exhibition, "Archives of XXth Century architects in the Marche region"; the Virtual Tour "Hue Tomorrow - Multimedia tools for the documentation and communication of existing architectural heritage"; the Multimedia tool for the historical site "Loreto: faith, architecture, tradition and art"

1. INTRODUCTION

1.1 General background

For several years, architectural representation has been using new digital tools and the DARDUS Department (Department of Architecture, Survey, Restoration, Drawing, Urban Planning and History, of the Polytechnic University of the Marche region) has performed important research based on the use of Information Technologies as tools for architectural analysis and communication.
The Dardus department of the Marche region Polytechnic has been involved in international scientific cooperation in the field of knowledge and valorisation of cultural heritage for 10 years. A dynamic international network involving universities, institutions, local authorities, enterprises and associations has been set up and is active, particularly in East Asia. The mode of cooperation that was developed over the years has led to an approach of the analysis of the language of architecture and restoration which recognizes that if the value expressed by the work is to be acknowledged and handed down to future generations, it requires first of all a critical and interpretive effort on the part of communities who are directly involved.
In this moment, the knowledge and diffusion of architectural culture is a productive multidisciplinary field for elaboration and telecommunication, a sector that crosses the humanistic values of Cultural Heritage with the scientific culture of Technological Innovation.
The limits of the traditional technique of freehand drawing are overcome by the digital world, which offers uninterrupted, unified readings by means of three-dimensional and multimedia data, while conventional two-dimensional representations are limited to discontinuous accurate representations of reality.
DARDUS organizes a triennial event in this field of research, called the e-Arcom Workshop, in which scholars, researchers and companies participate: this organization, launched in 2004, houses the international excellence of Information Systems applied to Cultural Heritage.
Information systems applied to architecture have a double advantage.
On the one hand, they are INSTRUMENTS OF KNOWLEDGE, a wealth of the third millennium, considering that "we passed from a post-industrial culture, in which the greatest goods for the society were material resources, to a reality where the main source of power is knowledge"; the access to information thus becomes an "estimation of knowledge that supports the economic and technological development of a country itself " (Bertini, 2003).
On the other hand, information systems become an INSTRUMENT OF THE PROJECT if we consider that analysis and architectural survey as critical readings provide metaprojectual data for the conservation of architectural heritage: electronic devices are a very useful tool for the collection of heterogeneous data such as texts, images and pictures that would otherwise be a sterile information system, instead of documents that are valid for the whole project (Pugnaloni, 2004).
Electronic devices and digital applications in architecture, in both analysis and communication, are also a valid tool in the promotion of monumental sites in the Asian area, where Dardus has been cooperating for several years in order to further the knowledge and enhancement of Cultural Heritage.

1.2 Objectives

In this context, the integration of surveys based on prompt photogrammetry, the subsequent creation of virtual models and the provision of Geographical Information Systems, allowed for an accurate reconstruction of the monumental complex, unknown sites with great international importance which are recognized by UNESCO as Worldwide Heritage.
The methods described above enable the acquisition of significant data in order to communicate cultural heritage using multimedia tools (Gaiani 2003).
The following are examples of communicating architecture using multimedia technology, relating to research which has been carried out in the last few years by DARDUS; they are demo applications of information systems as tools and instruments of popular design.

1.3 Methods and Technologies.

The following case-studies present some common methodological choices:
-The easy use of complex cultural content, which is the result of research;
-The integration of several systems of acquisition and their multimedia;
-The use of methods which are able to exploit acquired data (architectural survey, 3d models, movies, etc.);
-The use of programming and viewing tools which are available and prevalently open-source;
-To allow data to be cross-read and to create links between different contents.

Regarding technological aspects, products are created using the Flash platform, according to its numerous versions and updates. As a matter of fact, Flash is able to combine several types of content from a number of elaborations and acquisitions (laser scans, texturized .3ds models, ipg images, .avi motion pictures, interactive vrml models, etc.).
Data based on virtual reconstruction is elaborated using open-source software, such as Blender, and then exported as a vrml model or alternatively as .avi motion pictures. Documentation of existing settings is done by acquiring spherical panoramas using professional NikonD90 cameras equipped with Fisheye optics. Subsequently, the data is combined using the proper software, such as PTGui, and then loaded on the interactive visualizer Tourweaver.
The Flash platform enables all models to be integrated into one setting and it also enables the creation of links between objects according to thematic paths.

2. VIRTUAL EXHIBITIONS

The case of "Archives of XXth Century architects in the Marche region"

The work was developed in 2009 by the DARDUS Department in cooperation with the Marche region's Department for Archives and History and presents a census and activity relating to XXth Century architects in the Marche region in an exhibition (the archives of 35 architects preserved by private citizens or in cultural institutes such as libraries, Public Records and museums have been studied) and it also provided an opportunity for the realization of a multimedia displaying tool.
The final product, created with Flash Player software to ensure it could be easily used, forms a kind of digital exhibition catalogue, a dynamic model for collecting, managing and reporting historical architecture data with links to the field of research as well as the field of architectural knowledge. Information is disclosed by using visual documentation and interactive material.
Visual documentation involves a highly accessible form of data transmission which is able to collect and monitor information of different content, formats and consultation procedures; different types of information is organised in a relationship system.
Interactive material permits dynamic consultation of data and information is reproduced using a highly intuitive interface. A virtual exhibition is directly accessed by the user by making use of 360 ° spherical panoramas which are set up using web-based Tourweaver software so as to create a virtual tour; interactive navigation inside the exhibition space has hotspots connected to the plan.

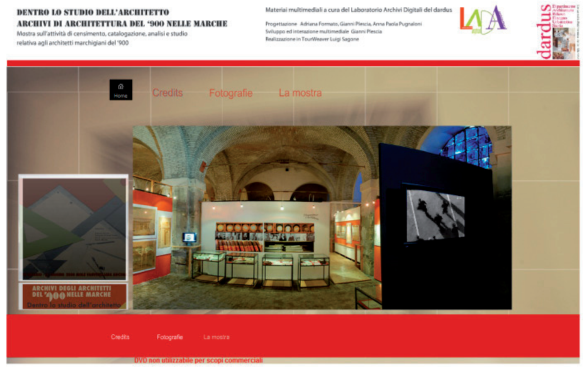

Figure 1: Virtual Exhibition

Moreover, as noted by Marco Gaiani, the means of representation of architecture in the third millennium "offer more than just digital access to analog artifacts. Digital media introduces various possibilities of dynamic knowledge. Potentially, digital technology allows each individual to create his or her own virtual equivalent of an analog collection, endlessly multiplying museums and cultural relationships and the whole cultural heritage of humanity is thus potentially available on the Web to different users and under different consumption patterns " (Gaiani, 2007) ..

Figure 2: Panoramic views of the real exhibition

3. MODELLING AND VIRTUAL TOURS

The case of "Hue Tomorrow – Multimedia tools for documentation and communication of existing architectural heritage"

As part of research conducted with the support of the Italian Ministry of Foreign Affairs on the historical city of Hue, Vietnam, UNESCO site since 1993, a multimedia tool for public diffusion was created. This instrument includes part of the research results, which were considered of particular interest by scientific coordinators and the local authorities.
In fact, the city of Hue has very complex urban issues, related to the widespread presence of important architectural monuments which are linked to natural systems.

Figure 3: Home page

The monuments, which have the Citadel and the Forbidden City in their centre, were studied and documented, and a reconstruction of missing parts was hypothesized, particularly buildings inside the Forbidden City and the temples along the Perfume River. Along with this phenomenon different historical, cultural and philosophical values were noted. These were deducted from a study of urban history and are hidden. The system of cultural heritage is in direct relationship with the river as is the ring of fortifications belonging to the citadel and the imperial tombs located in the mountains surrounding the city to the west.

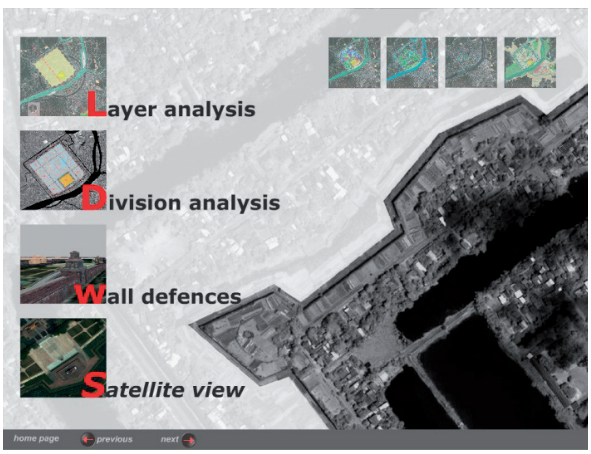

Figure 4: Analysis of the monumental site

The urban plan is inspired by the rules of feng-shui, which relate the forms of the city to their function, according to an ideal of harmony and wellbeing between man and nature. These values are still present in the city, though they are difficult to detect, because of urban density that tends to obscure those parts of the city which were originally planned according to spatial relationships.
A multimedia tool has been inserted here in order to allow a reading of organic urban and architectural values. The basic documentation consisting of the results of scientific research was selected and further developed. Using photogrammetric surveys, models and virtual environments were created, relative to the current situation of the city, founded in the late eighteenth century. The contents are aimed at a popular audience with an appropriate cultural background, who are interested in studying the architectural features of the city. At the same time, it was intended to be an instrument for the inhabitants of the city of Hue, allowing them to rediscover values and a sense of identity.
At the technical level, a multimedia product based on Flash has been set up and optimized for local use via DVD. This was chosen over web communication for three main reasons: the need to protect intellectual property data and the difficulty of publishing particularly complex three-dimensional models on the web, the low availability of fast internet connections in Vietnam, compared to a large number of PCs in institutions and private homes. In order to meet the needs of the different targets, we defined two possible paths of multimedia knowledge. A first level, shared by both paths, provides historical data on the evolution of the architectural culture of Vietnam, from its beginning. This section makes use of tools that facilitate rapid and effective communication, concentrating especially on short videos, audio segments and texts. A second level gives the user a clear and comprehensive understanding of architectural quality and urban areas. To this end, the multimedia product navigates the virtual environment of the historical city, illustrating different themes: the old streets, the relationship between monuments and the environment, the traces of feng-shui.

Figure 5: 3d model and virtual environment

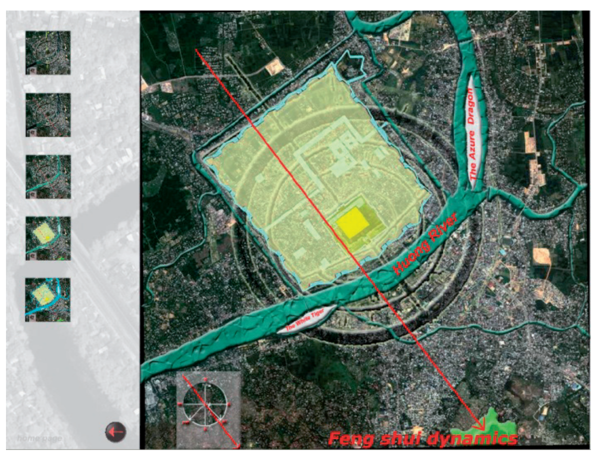

Figure 6: Multimedia visualization of urban analysis

Models of virtual environments have been based on photogrammetric surveys conducted by the research group, allowing a degree of precision appropriate to the communicative function of architecture in its geometrical, formal and material aspects. The purpose of the virtual model is the maximum enhancement of the monument, freed from the recent urban developments that make it hard to recognize. Exploring virtual environments can be seen as an instrument which is participatory and in depth. The level of detail of the model and textures allows an assessment of formal and constructive solutions, volume and advice on the historical city's technical systems, ramparts and gates. At the same time it can communicate simple concepts to people who have no experience of historical architecture, providing a picture of the whole complex which can arouse curiosity and awareness in the city. The third and final phase of the multimedia product offers strategic planning choices. They are chosen by the research team and local authorities. This phase is aimed at two target users, and aims to stimulate the participation of citizens and scholars in the planning of Hue tomorrow. To facilitate a comprehensive perception of strategies, the third section uses a virtual model of the entire city, kept deliberately free of texture, in which the design concept for urban renewal was included. The use of virtual environments has been prepared using multimedia formats (. Avi and . Mpg) according to predetermined paths and registered. The size of the model did not permit free interactive navigation in the VRML format; this would have required all visible parts to be more thoroughly modelled (Issini, 2008).

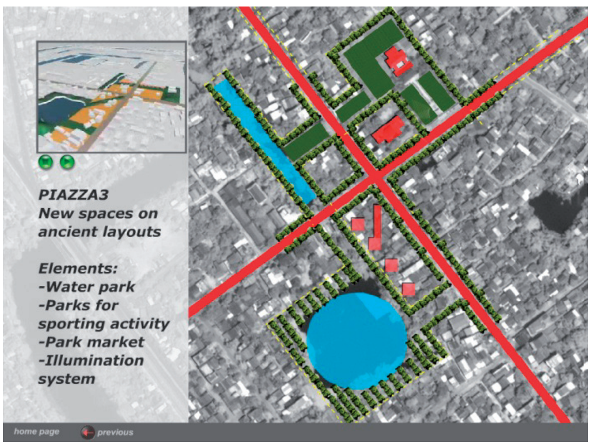

Figure 7: Preliminary design strategies

Figure 8: Interactive tour of the Virtual Environment

4. MULTIMEDIA TOOLS FOR HISTORICAL SITES

The case of research "Loreto, faith, architecture, tradition and art"

As part of promotional activities which were part of the Jubilee 2000, the Marche Region commissioned the Dardus Department to create a multimedia product based on the Basilica of Loreto which houses the Holy House. This product is designed for the diffusion of research carried out on the city's historic centre, on urban development resulting from the movement of the Holy House, and analysis of developments in the architectural appearance of the Basilica, up to the current situation. Its use, in this case, was only required locally.

Figure 9: Home page of the historical sites multimedia tool

From a technical point of view, the multimedia tool was created using Macromedia Director. An interactive panorama of the interior and exterior was added in Quick Time format.
The target audience was a public with adequate knowledge of art, architecture and religion. Contents are divided by media formats (audio, video, quicktime) in a dialogue between three themes (art, architecture, religion). The historical value of the site can only be described when it is considered as a whole unit.

Figure 10: Themes selection

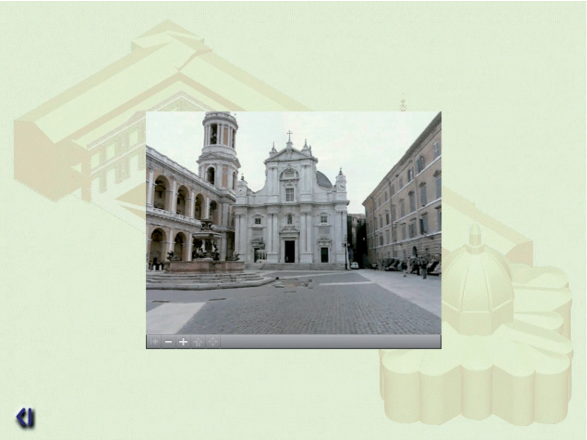

Figure 11: Interactive visualization of the historical site

In-depth thematic studies of historical documentation were created for users who are more attentive to historical facts and have a greater understanding of architecture, which over the centuries has counted prominent figures such as Bramante, Sansovino, Giuliano da Majano, Giuliano Sangallo, Antonio da Sangallo the Younger, L. Ventura, G. Boccalini, G.B. Chioldi, L. Vanvitelli.
Using a digital model of the architecture that overlooks Piazza della Madonna was essential for showing the architectural evolution of the site. In fact, the digital models show how the urban area has developed around the site of the Holy House, with a succession of basilicas which led to the formation of the entire historical centre and the current situation.
The advantage afforded by digital models as the content of multimedia communication products is precisely in this opportunity to combine real values, which could only be represented partially using traditional systems.
In this case, the virtual model not only serves as a tool where information derived from intrinsic and extrinsic documentation found an organic application, but also keeps the formal values of the original town, which can help when new work or restoration projects is being chosen.

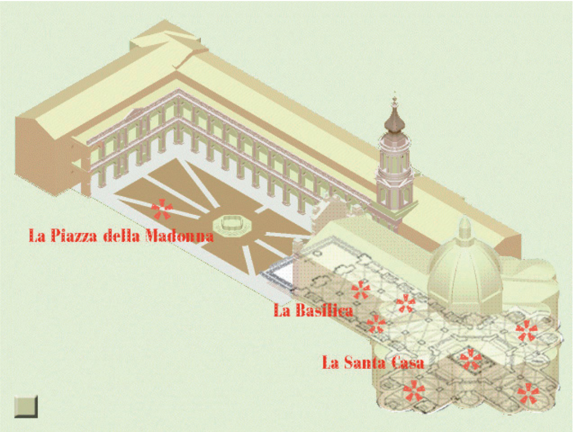

Figure 12: Monument point of views

5. CONCLUSIONS

Skills and times are now ripe so that the traditional forms of architectural communication can embrace technology which only a few years ago could have appeared misleading; they also bring together disciplines that seem distant and by comparing their aims they find useful similarities in the representation and communication of architectural images.
The hope is that this difficult meeting of culture and technology, image and number, may soon become a unique tool for the protection, enhancement and communication of our heritage, no longer confined to strict academic research fields, but available in the free and open “market "of a civil society which can express itself and transmit the beauty and the richness of its history, cities and places to the world and to the future.

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3D MODELLING OF A TOWN SCALE MODEL

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KEY WORDS: 3D modelling, parametric modelling, architecture, cultural heritage, photogrammetry, lasergrammetry.

ABSTRACT:

This paper presents a new "top-to-bottom" method for the 3D modelling of towns. This method was first tested in the case of a town scale model made of wood and paper. One of the applications that will be made with the 3D model is a web application. The model has to be light but reliable. From skeletons of the roofs extracted from pictures with PhotoModeler, we automatically build the 3D model of the town with the following points automatically handled: classification of the segments and of the kind of slopes, incoherences due to precision errors between segments of a roof and between roof outlines, overhang parameter values. Results are promising

Figure 1: Scale model of Toul

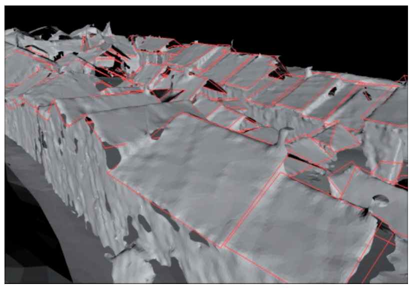

Figure 2: 3D segments on the laser data

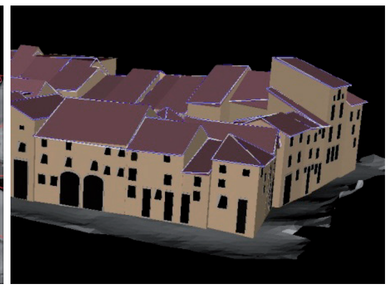

Figure 3: Automatic city block reconstruction

1. INTRODUCTION

The needs of 3D models are currently numerous for various uses: scientific studies (evolution of building deformities-vaults for instance, digital terrain model, petroleum reserves, volcano studies, etc), virtual visits (ancient or destroyed cities or monuments), historical studies of towns (scale models of town, hypothesis of building construction), illumination simulation projects of historical monuments, etc.
We work for the "Musée des plans-relief" (Museum of town scale models) in Paris and for the "service régional de l'inventaire général de Lorraine" (historical research centre) on the 3D modelling of the scale model of the town of Toul in France (Figure 1). The scale model of Toul was built in the 1840s and modified in the 1860s. It is composed of 20 pieces (called tables). The biggest table is the one containing the town (2.31 x 2.23m). The other tables contain the countryside. We were asked to model the town table and a table from the countryside (1.50 x 2.50).

Why model the scale models?

- Interactive terminals for the museum: there is no visibility of the town parts of the scale models because they are too big. They are behind glass to avoid dust deposit.
- Web application: navigation in the virtual model will be a means to access further information via the model.
- Most of the scale models are stocked in boxes where nobody can see them. It is the case for the scale model of Toul. Only 26 of them are exposed in the museum.
- For the researchers in history.
- For cultural heritage conservation.

Research problems are related to this project. They are at the mid-point of two research fields: photogrammetry and lasergrammetry on the one hand and 3D parametric modelling of architectural elements on the other hand. It is still unthinkable to obtain automatically a 3D scene composed of architectural parametric elements. However it is possible to automate some steps with a restricted user help and an adapted user interface.
In this paper, we present the method we have conceived and developed for the 3D modelling of scale models of towns. After a presentation of related works (part 2), part 3 explains the context of the project. Then the principles of the method are explained in part 4. Part 5 deals with the parameters and constraints we have identified for the creation of the architectural elements in the scale model. Some results are exposed in part 6. Finally, we conclude and present future work in part 7.

2. RELATED WORKS

Several works are undertaken in modelling scale models of cities. The model of Prague by Antonín Langweil in 1826-1837 is one of these projects. It involved a large team, more than a hundred people for just the 3D model reconstruction step. The digitizing was accomplished easily because the model can be divided into 52 parts (1.6 x 1m for the biggest with a scale of 1/480). It is in much better shape than the model of Toul but the buildings' textures contained thin structures of drawing in

Indian ink (the measured details corresponded to roughly 1200 DPI) making textures and their digitalisation more delicate than ours. The model was carried out thanks to the collaboration of Autodesk and the use of photogrammetric software adapted and developed especially for this project (Sedlacek 2009, [7]).

In the 3D modelling of Beijing city scale model (Zhu et al, 2009), the authors use stereo image pairs of the object to improve the quality of edges of the scanned model. The point clouds are improved but no modelling is made and no semantic is given to the model. In our project each building needs to be identify for the web application with links anchored to buildings.

In the 3D modelling of Rome scale model [8] (Guidi 2005), models of complex buildings were created with Maya [5] and the others were computed with the hemp of procedural and parametric modelling techniques (city Engine [11], Dylla 2009).

Some research in photogrammetry and lasergrammetry create meshes from either laser point clouds or image-based point clouds and improve the quality of the edges and surfaces (Hoppe 2009, Barazzetti 2009, Fisher 2003, Zhu et al 2009, Sedlacek 2009). The main drawbacks of these methods remain the large amount of data (a simple surface like a cylinder will be composed of many points), the lack of semantic means (all objects are grouped in one big mesh), the lack of accuracy of edges (due to the sampling process of a laser scanner), absence of parts of the model (some parts are always hidden by foreground objects).

Other research extract geometrical data (roof planes) from point clouds (acquired from either laser scanning or images) and then build the 3D model of the houses from top to bottom (Vosselman 2001, Tse 2005, Tarsha-Kurdi, 2007, Boulaassal, 2009, YingYang 2010, Rottensteiner 2005, Maas 1999). (Pu and Vosselman, 2009) manage not only to rebuild automatically the 3D model of houses but also their openings.

As far as computer vision is concerned, extraction of segments or regions from images are also another research field of many teams (Werner 2002, Suveg 2002, Heuel 2000, Jaw 2008, Ameri 2000, Taillandier 2004…). (Hendrickx 1997, Koehl 2007, Moons 1998) use geometric properties to label each segment of a roof. Koehl divides data in tree layers: outline segments, every segment inside the outline and the roof slopes. He uses TIN (Triangulated Irregular Network) algorithms to triangulate roofs but problems involving complex roofs still appeared.

Few top to bottom methods deals with wall interpenetrations of juxtaposed buildings with constraints (Suveg 2002, Lafarge 2006), relationships between neighbouring roofs (gaps or overlapping slopes) and overhangs or verges.

On the other hand, there is research in architecture for the 3D modelling. Two kinds of research can be specified: 3D models for conception goals and 3D models for patrimonial or archaeological goals (Chevrier, 2009). The use of architectural 3D parametric components allows a quick and accurate modelling. For example, once the roof is modelled, roof superstructures constitute an accuracy asset for photorealism issues. A parametric model (Brédif, 2007) specific to several superstructure types is a fast way to attain this aim. However the adjustment of the parameters of the virtual 3D model in order to fit the real one is tedious. Some components are easily identifiable, the presence or not of a keystone, a type of roof, etc. but the value of a geometric parameter (length, radius, etc.) cannot be close to reality without additional data like surveys, photogrammetric or scanned models.

In this paper we use a top-to-bottom method and we handle automatically the following points: classification of the segments and of the kind of slopes, incoherences (correction of parallelism, and interpenetration) due to precision errors between segments of a roof and between roof outlines, overhang parameter values. Then a Graphical User Interface allows manual corrections and the adding other components to the 3D scene (openings, chimneys, belt courses, quoins, vegetation…).

3. CONTEXT OF THE PROJECT

The aim of the project is to get a virtual 3D model of the scale model of the town of Toul in France (Fig 4 and 5). Compared to a 3D modelling of a real size town some specificities can be noticed:

- The size of the houses is very small: the scale is 1:600 that means approximately buildings of 2 to 3 cm high, streets are about 1 to 2 cm wide with some alleys of less that 5 mm wide.
- There is just the essential on the scale model: no perturbing objects in the streets (trees, urban furniture).
- The scale model is in a bad state: papers are unstuck or missing, a lot of dust is on the model, slopes are skew surfaces (Figure 1)
- Digitalization has to be carried out without contact, purely on optical principles.
- Given the fact that some areas of the model are not easily accessible, many houses cannot be well documented.
- Moving the model without a skilled team to access some areas is impossible because of the size, the weight and the fragility of the model.

The following parts explain the problems we encountered with the acquisition of the data: laser data (part 3.1), pictures (part 3.2) and with the use of 2D documents (part 3.3).

Figure 4: Photograph of the scale model of Toul

Figure 5: Photograph of the town table of the scale model of Toul (2.31 m x 2.23m)

3.1 Acquisition of the laser data

We were not allowed to touch the model. After much discussion we were authorized to lay several sewing threads in surrounding streets. We encounter difficulties in accessing the inner blocks and thin roads (Figure 6) The laser data will only be used for the numerical terrain model (DTM) on which we will build houses and plant vegetation.

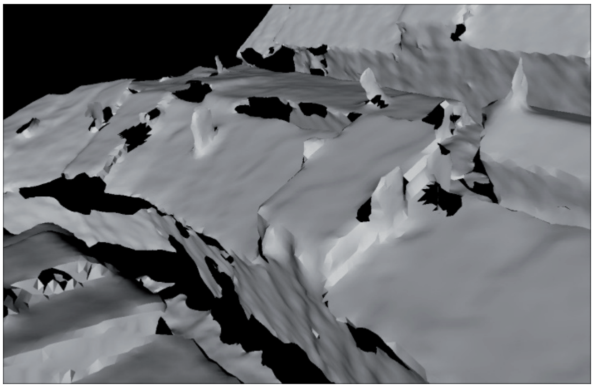

Figure 6: scanned parts realized with a precision of 0.5 mm. A resolution of 0.5 mm is a good compromise between time spent and quality.

3.2 Acquisition of the photographs

As mentioned, the size of the town part raised difficulties to access several city blocks. Due to the width of some streets or the density of buildings – especially in the centre of the model – photos did not show every part. Bad lighting conditions and bad contrast due to dust deposit increased the amount of time spent in taking pictures. Tests with PhotoModeler Scanner were not workable because of the bad quality of the photographs and of the bad state of the scale model itself.

3.3 No-Use of the 2D documents

Regarding the ground plans and elevation plans, there were some contradictions with the model because of lack of precision or modifications in the city the during time lapse between the making of plans and the creation of the scale model. Actually, they were not ground plans but rather a hybrid of roof plans and ground plans. That's why many incoherences appeared making the use of these documents tricky.

While we wanted to create our model thanks to these documents, it appeared impossible to rely on them. Without ground plans and elevation plans, modelling relied only on photographs with the use of photogrammetry techniques. We have developed a “top to bottom method” specially adapted to scale models that can have irregular geometry and complex roof configurations.

4. PRINCIPLES OF THE METHOD

To create a 3D model, many tools are at our disposal. From Image-based process (ImageModeler [4] or PhotoModeler [6] software) to range-based modelling (3Dipsos [10], Geomagic [3] or polyworks [12]), even traditional geometry-based software (autoCad [2], archiCad [1]). Combining several technologies where they are best suited is one backbone of this work. Photogrammetry alone is not appropriate to build irregular shapes like sculptures or, in our case, ground relief whereas laser scanning is an awkward choice to digitalize flat surfaces like roofs.

Thus, we have begun by recovering roof edges (part 5) thanks to PhotoModeler [6], a photogrammetric software. At the same time, the scanned ground geometry (digital terrain elevation DTE) has been manually treated with Geomagic [3] to create the digital terrain model (DTM): all the parts above the ground (buildings and vegetation) have been removed and holes have been filled to get the entire terrain model.

Automatic treatments on the 3D segments of the roofs allow removing excess points or segments, correcting parallelism between edges and fusion between close points (part 6). Then an automatic 3D modelling of the roofs and walls can be performed taking into account some parameters and constraints like the planarity of the roof slopes (part 7). The DTM is used to set up the walls of the buildings (to find the ground polygon corresponding to the building). As the 3D model will be primarily used for a web navigation, we have chosen to replace the DTM corresponding to the roads and below the buildings with a Delaunay triangulation of the encompassing area with holes corresponding to the buildings. For this we use the free software developed by (Triangle [9]). Finally manual refinement can be applied locally to the 3D model to adjust or correct parameters and constraints (part 8).

In all steps of the process, it is possible to use specific user defined thresholds. Every step can be cancelled to try other values of the thresholds.

5. SEGMENTS CREATED WITH PHOTOMODELER

The first step is a photogrammetric method involving the manual digitising of a minimum number of data necessary for the treatments to follow. To obtain the finished house model only the roof skeleton is needed.

In the results from PhotoModeler, every surface is a skew surface, no line is perfectly parallel to another, roofs and walls of the houses can penetrate each other, etc. It is true that bad orientations in PhotoModeler or inaccurate point positions contribute to this kind of geometry but most of the model is so damaged (unstuck papers) that its geometry has become irregular. Nervertheless, we are able to use the accuracy of each PhotoModeler point in our further treatments to balance or advantage the position of some points or segments compared to others. Combined with automatic treatments (part 6), parametric objects and an adapted user interface, we can make the 3D model more accurate. The great majority of the roof slopes were designed planar surfaces because their realisation is easy. Skew surfaces are unusual but we keep them skew if they were designed skew or if their bad states do not allow us to recover their initial shape.

We work city-block by city-block with oblique pictures. The accuracy of the photometric data is around seven pixels for all the city-blocks. This high level is due to imprecise points we had to position although they were not seen in any picture or to points in blurred parts of the pictures. This accuracy corresponds to approximately half a millimetre. The segments are positioned automatically on the DTE with the help of three selected points in the DTM and the three corresponding points in the PhotoModeler data. This allows us to scale and orientate the segments. Manual refinement is possible if necessary.

6. AUTOMATIC TREATMENTS

6.1 Separating the total set of segments into small sets corresponding to a roof

The segment set is divided into small segments corresponding to a roof or sometimes a complex roof or a group of roofs. For a given segment, we look for all segments that are connected together: it means that they share a same point. If two roofs share a same point, there will be only one set of segments for the two roofs. This is not a problem as the following algorithms handle this case. We often have complex roofs and even a user does not really know how to separate pieces in several roofs (See Figure 7 for an example).

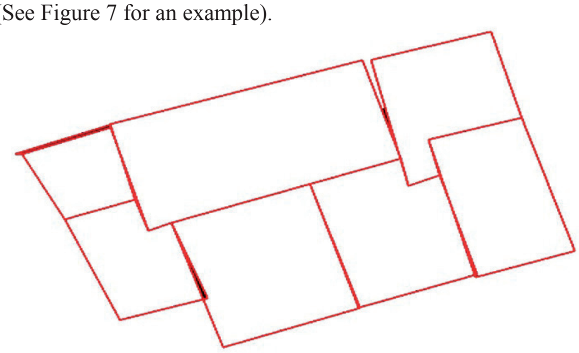

Figure 7: Complex roof structure detected as a unique roof. However the further classification and treatment correctly handle these cases.

In PhotoModeler, as we have seen in the previous section, there are sometimes exceeding points or segments. We then look for closed points (distance less than a given value). We only keep the most accurate point and also remove the double segments.

6.2 Classification of the roof segments

This step aims to identify the outline and the slopes of the roof. It also determines the type of each segment of a roof: ridge, roof edge, angle or valley, roof break, head edge and eave (Figure 8). Each slope is also classified for automatic corrections and material assignment: a normal slope (slope, hip, upper slope, half hipped) or a break.

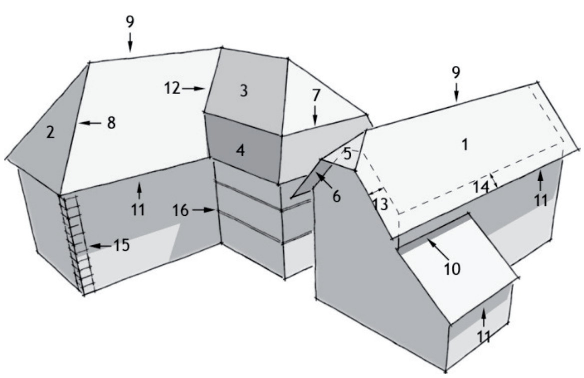

Figure 8: Various kinds of segments for the classification. (1:slope; 2: hip; 3: upper slope; 4: break; 5: halp pipped; 6: roof edge; 7: roof break; 8: angle; 9: ridge; 10: head edge; 11: eave; 12: valley; 13: verge; 14: eave overhang; 15: quoin; 16: belt course)

To determine the outline of the roof (encompassing polygon), we use an algorithm based on the detection of a bounding polygon of a set of points:

Algorithm
Outline O
Point B = the point with the lowest horizontal coordinates (x and z). Y axis is the vertical line.
Segment S = X axis
While there are segments in the set and we have not returned to point B
do
Among the set of segments, select the one (called S2) that has the smallest angle with the segment S
Remove S2 from the segment set
S = S2
Add S2 to O
endWhile

To avoid bad results with complex roof shapes due to bad alignments of segments (overlapping slopes in Figure 7), we had to make the algorithm robust by taking into account these cases in the computation of the angle.

Once the outline of the roof has been computed, angles and valleys are easily separated because there are not horizontal segments (with a given threshold). The remaining segments are ridges and roof breaks. In the same way, we identify roof edges in the outline of the roof. The remaining segments are eaves. For roofs with no other segments than the segments of the outline (it means roofs composed of only one slope), we identify a head edge among the edges as the higher segment (or highest segments in some cases).

Almost the same algorithm is used to identify all the segments that belong to each roof slope. The algorithm is adapted based on the consideration that a segment belonging to the outline can only be used once whereas the other segments can be used twice (they separate two roof slopes).

Algorithm
While there are segments in TSS **do**
Create a slope
Segment S = first segment in the total segment set of the roof (TSS)
If S is a segment from the outline **then** remove S from TSS
Elseif the number of times we have used S2 is one **then**
Remove S2 from the segment set
Else Mark the S as used once
Endif
Add S to the slope
While we have not returned to the beginning point **do**
Among the set of segments (TSS), select the one (called S2) that has the biggest angle with the segment S
if S2 is a segment from the outline **then**
remove S2 from TSS
Elseif the number of times we have used S2 is one **then**
Remove S2 from the segment set
Else
Mark S2 as used once
Endif
S = S2
Add S to the slope
endWhile
endWhile

The roof slopes are then automatically classified as normal or break slope. This allows assigning a specific material to the different parts of the roof during the modelling process. Indeed a break slope is usually in slate whereas a normal slope is usually made of roof tiles. In case of errors in the classification, manual correcting can be applied: The user interface lets us access each segment or each slope in order to modify the kind.

6.3 Corrections of parallelism and fusion of points

In order to obtain realistic shapes similar to the physical model, we have to constrain roof geometries inherited from bad orientations in PhotoModeler. The other goal of this measure is to prevent building imbrications.

The first kind of corrections we make are parallelism corrections. This is done in 2D (XZ plane ; Y axis is vertical) First in a same roof outline, neighbouring roof-edge segments that are almost parallel (to a given threshold angle) are put perfectly aligned. Then each segment of the outline is compared to the neighbouring outline segments of other roofs.

If the two segments have an influence on each other we superimpose them or we make them parallel according to a certain threshold: if the distance between the two segment midpoints is less than a certain value (0.05 cm for example in our case) then we superimpose them. If the distance between the two segment midpoints is less than a certain value (0,4 cm for example) then we make them parallel.

To determine if two segments have an influence on each other, we proceed as follows: first we consider that one roof can have an influence on another roof if the distance of their weighted centres is less than a given threshold. This eliminates quickly distant roofs. Then we apply the following algorithm:

Algorithm
For each segment S1 of an outline roof R1 **do**
For each segment S2 of an outline roof R2 **do**
If the angle between the two segments is less than a given threshold and the distance between their midpoints is less than another threshold **then**
Project the points of S2 on the line defined by S1
This defines the length of the common part on the line
Float k1 = length of the common part / length of S1
Float k2 = length of the common part / length of S2
Float k = k1 + k2
If k > another threshold **then**
S1 and S2 influence each-other.
Endif
Endif
Endfor
Endfor

To determine if S1 has to be aligned or superimposed on S2 or the opposite or if both segments have to be moved along a mid median, we use point precision and some criteria based on the length of each segments: a small segment (corresponding to a sloping roof for example) will be moved to be aligned to the other segment (the wall of a house for example).

If two segments have an influence on each other and if these segments are roof edges we also correct other connected roof edge segments.

This constraint of parallelism also allows us to determine the overhang values. At the beginning of the process every roof-edge segment has a user-defined value and every eave segment has another user-defined value. When two segments are superimposed, both the overhang values are set to 0 (Figure 9).

When two segments are put parallel, if the roof R1 and roof R2 have a common part, we study their relative position in 3D (not only of the 2 segments but also of the connected roof-edge segments if necessary): if the polylines thus defined intersect each other, both the overhang values are kept (parts of the segments of the two buildings have overhangs and parts do not have any overhangs). In the other case we determine the polyline that is above the other: the segments of the above polyline keep an overhang value that is equal to the distance between the two segments and the segments of the other polyline have an overhang value set to 0 (Figure 10).

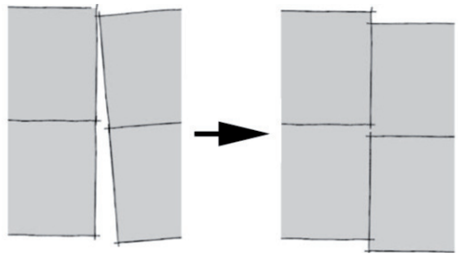

Figure 9: Constraints of parallelism to determine overhangs

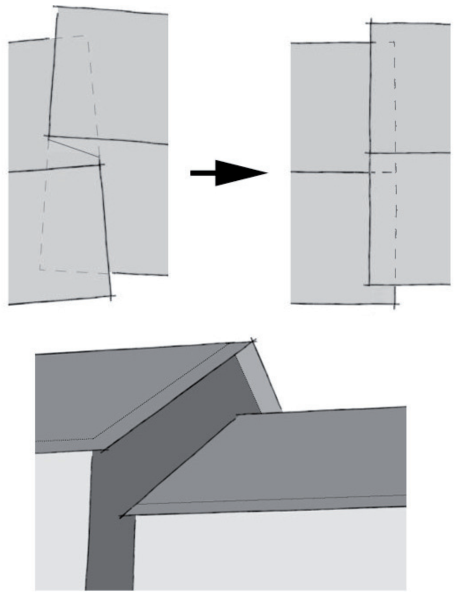

Figure 10: One polyline is above the other: only the overhang of the highest polyline is different to zero.

Thresholds are chosen to maximize the right corrections without wrong corrections. After the process, if the result doesn't suit the user, he can cancel the corrections and apply again the process with other thresholds.

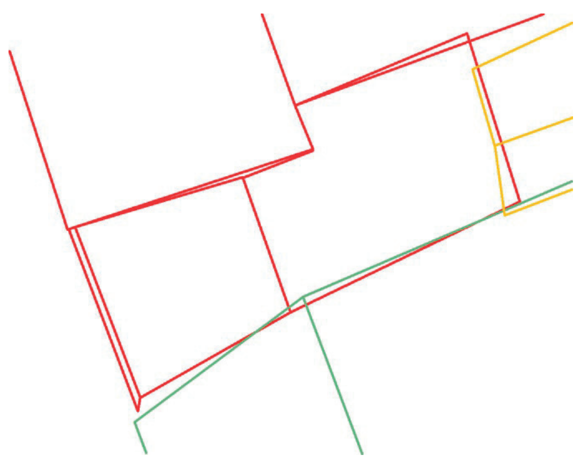

Figure 11: Interaction of three different roof skeletons in three different colours. One can see the parallelism errors between segments.

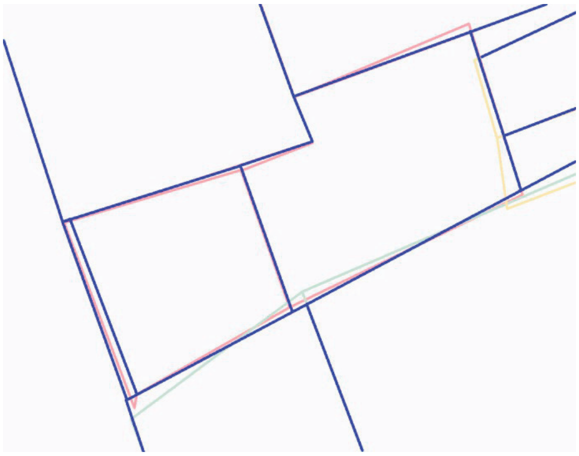

Figure 12: Automatic corrections of parallelism between segments of a same outline and between outlines in the cases of the three outlines of Figure 11.

7. AUTOMATIC 3D RECONSTRUCTION OF HOUSES AND DIVIDING WALLS

Based on the classification of the segments composing a roof, we can now automatically create the 3D model of the corresponding house. Parameters and constraints are defined for all buildings for this step but each parameter or constraint will be able to be modified for each house in the next step is necessary (manual refinement). The main parameters and constraints taken into account in this step are: a value for the thickness of the roof, planarity of the roof slopes, horizontal ridges. Parameters have default values that are the most common values encountered. Constraints are the most common.
The constraints are first taken into account to modify the position of the points. Each ridge is set to horizontal (taking into account the accuracy of the points or according to the mid point of the segment).
Then, for each roof slope, the planarity is applied: the ridge is supposed to be well positioned, the most precise point among the other points of the slope is selected to define the supporting plane of the slope. The other points are then vertically projected onto this plane to be positioned.

Algorithm:
Foreach segment of the roof outline **do**
- Compute the offset points due to the roof thickness, perpendicular to each roof slope it belongs to. The position of a point depends on the offsets due to the two outline segments that share that point.
- Compute the offset points due to the overhang of each segment.

Foreach roof slope **do**
Create the polygon of the slope
Foreach segments of the slope **do**
If the segment belongs to the roof outline **then**
Create the polygon corresponding to the roof thickness
If the overhang of the segment is > 0 **then**
Create the polygon corresponding to the overhang
Endif
Endif
Endfor
Endfor

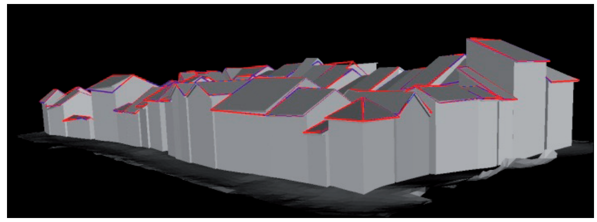

Figure 13: Automatic 3D model obtained from the roof skeletons. Slopes are initially set plane and ridges are set horizontally but the user can modify these parameters to adjust the model.

8. USER INTERFACE FOR THE ADJUSTMENT OF PARAMETERS AND CREATION OF OTHER OBJECTS

As in any automatic process, most of the corrections are pertinent, but in some cases they are not pertinent or some problems have not been corrected whereas they should have been. This is due to the values given to the thresholds used during the automatic process. We have then developed a user interface to apply locally some constraints or modify values of the parameters. It is thus possible to select a segment and to apply locally some treatment (the same as the automatic ones but only for this segment with user-chosen thresholds). For wrong automatic corrections, it is possible for a specific segment to cancel the automatic treatment. Values of the parameters can be adjusted for each segment or each roof. Finally it is also possible to modify the position of a point if the constraints failed for that specific point.

8.1 Parameters and constraints

Parameters for segments are: type of segment (ridge, edge, angle or valley, break, head edge and eave) and an overhang value. Parameters for a roof are: roof thickness, roof slope planarity, horizontal roofing, eave overhang, parallel roof edges and ridges.

8.2 Adding other objects to the model

Openings, dormer windows, belt courses, chimneys are all treated thanks to parametric objects. We distinguish objects attached to the walls (openings, belt courses) and objects attached to the roof (chimneys, dormer windows).
We have identified all the kinds of objects and realized a 3D model of each kind with a modeller. Each model is bounded in a square 1 by 1 cm and 0.1 cm deep. To position an object on a wall we then specify the type of object, the wall of the building on which the object must be stuck, the height, width and depth of the object (3 scale factors applied to the model), the x position along the wall, the y position in the vertical direction. We can also specify other parameters to simplify duplication of a same object:

- number of objects along the wall, horizontal interval between objects, boolean that indicates if the objects are centred along the wall with a possible lateral interval.
- number of objects vertically, vertical interval between objects,
- index of a removed object from the duplication: another kind of object takes the place of the previous object (generally a door instead of an opening)
- boolean that indicates if the object is as high as the wall and a boolean that indicates if the object is as wide as the wall (generally used for belt courses).

To position an object on a roof, once the kind of object has been chosen, and its position calculated, the bottom points of the objects are projected onto the roof slope to produce a correct lay out. For complex objects (like a construction on the roof of another one), a parametric object is positioned on the roof.

9. RESULTS

The town was decomposed in blocks. Each block was treated separately in PhotoModeler and then in our software for automatic treatment, manual adjustments and for the adding of other components. The town is approximately composed of 4000 buildings. We classified the buildings of 20 blocks according their roof shape (see Figure 14).

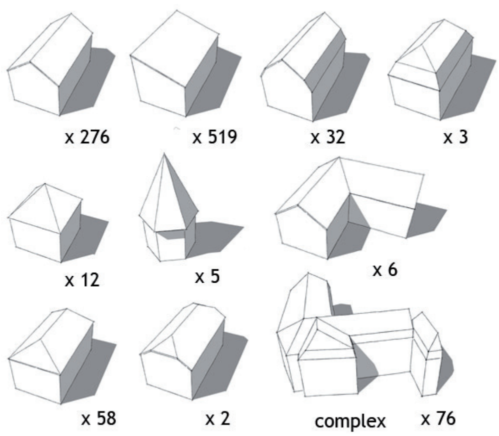

Figure 14: Classification of the roofs found in the scale model for 20 blocks and 898 buildings

Figure 15 and Figure 16 show examples of blocks with openings and chimneys.

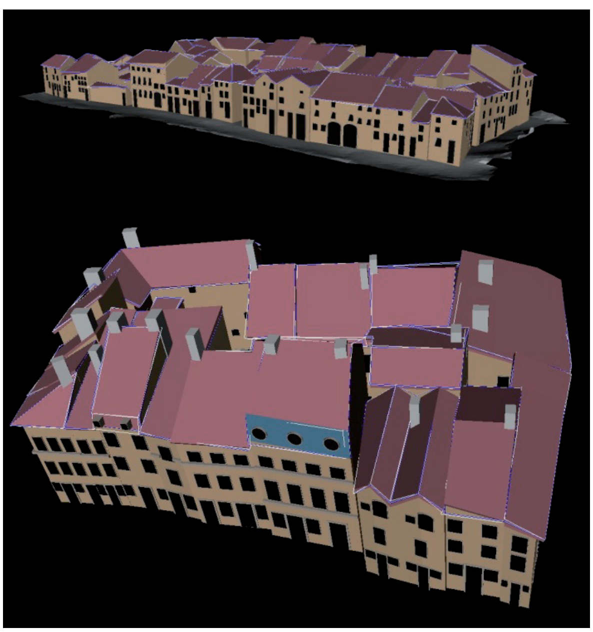

Figure 15: 3D model of blocks with elements added to the automatic creation: openings, belt courses, chimneys…

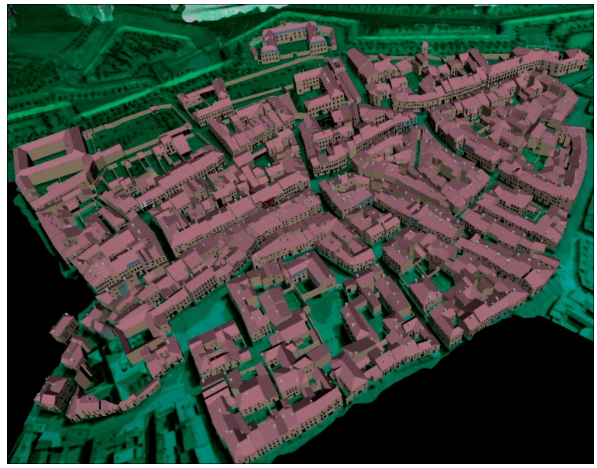

Figure 16: A view of the 3D model of several blocks

10. CONCLUSION AND FUTURE WORK

In this paper we have exposed the methods and algorithms we have used for the reconstruction of a scale model of a town. This scale model was made in wood and paper. Its bad state obliged us to have the possibility of keeping skew surfaces. An automatic and accurate classification of the segments of the roof skeletons allowed us an entirely automatic 3D modelling with automatic determination of the values for the mains parameters. The user only interfered when errors occured or adjustments had to be made.
In the future, several important points could be improved or tested:

- Try our methods on existing towns (aerial photographs and laser data).
- Improve the step of acquiring the segments of each roof. This step is carried out manually with PhotoModeler software. For this we plan to collaborate with researchers in computer vision and photogrammetry.
- Implement automatic techniques for the positioning of textures.
- make use of the DTE to adjust the roof geometry with an automatic detection of planes as in (Tarsha-Kurdi, 2007) for example.

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TEOTIHUACAN – A CASE STUDY IN THE USE OF DIGITAL TOOLS TO FURTHER THE CAUSES OF REGIONALISM AND PRESERVATION OF CULTURAL HERITAGE

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KEY WORDS: Digital Tools, Visualization, Regionalism, Preservation of Cultural Heritage

ABSTRACT:

This paper presents the findings of a research project on housing in Teotihuacan – an ancient Mesoamerican city – where new digital tools where used to bring to our times critical findings in support of regionalism. The research phase of the project included detailed archaeological investigations that concluded in three-dimensional theoretical visualizations of selected housing compounds within the ancient city of Teotihuacan. In addition to the fully rendered imagery detailed illustrations covering planning, architecture, and construction aspects were also produced. At the end these graphic materials resulted in a much clearer view of what the ancient city looked like. In turn, very important clues on regionalism have emerged and significant urban action has ensued. These propositions and conclusions are presented in detail in the paper.

Figure 1: Temple of Quetzalcoatl at Teotihuacan

1. INTRODUCTION

A person may know everything else, but remains ignorant if he or she does not know about the best achievements of his or her own ancestry.
Charles Eliot Norton

There is an old Moroccan saying "Ne parle qu'après avoir réfléchi et ne selle (le cheval) qu'après avoir mis la bride" ('think twice before you do whatever' or 'more haste less speed'). Countless communities around the world have not heeded this wise advice. In the rush for modernization, they have sidestepped the opportunity to ponder and assess the consequences of rapid growth and profound social transformations. The result has been brutal. Hassan Fathy (Fathy,1976) noted Egyptian architect, wrote '...in the outskirts of our provincial towns where construction has been more recent, there exists a stacking of overcrowded boxes of all sorts and dimensions, with a style copied from the poorest quarters of large cities, half-finished or not completed at all, in a state of disarray, in absolute disorder, piled up with no rhyme or reason, within a sad jungle of unfinished pathways, with clothes dangling from wires all over, with dust and garbage, and chickens running left and right…"
Not much has happened since those words were written in 1969. Fathy's prognostications were even more poignant when he anticipated that in those horrendous tenements homeowners would squander hard earned monies 'accessorizing' and 'decorating' their humble abodes with the most awful taste, and making the situation even worse, setting aside the benefits of authentic local artisan production. He concluded by declaring that this disrespect for tradition would inevitable result in towns growing uglier and uglier. His prophecies have sadly become true: not only each new building has compounded the problem but most actions intended to remedy the situation have made it worse.
Fathy argued that the root of the problem lies in the process of decision making. In order to get work, and to convince his potential clients that they will benefit from 'modernization', the

local unassuming builder begins to experiment with styles and building technologies he has seen somewhere else. In some instances he does not even understand how these new construction 'styles' work. Is this individual concerned about tradition? No, because he has not looked at how older approaches could apply to the present or simply does not know about local history and traditions. Moreover, it is generally assumed that because tradition is not 'modern', it is not 'good'. He therefore ignores the safe guiding principles of the past, and without further assist from the experience of educated architects, he then tries to produce 'architecture for the architects'. The final result is construction with all sorts of problems and none of the advantages of the work executed by good architects.

Herein lays one of the fundamental issues that the contemporary quest for regionalism needs to face. Many have justifiably admired solutions to problems posed by climate and available materials and the originality and thrift of solutions of architecture in antiquity. However, with a few notable exceptions architectural historians and a host of other groups including professional associations have paid little attention to the central role of older environments and their links to the social, economic and cultural life of populations today. This paper argues that while the praise has been ingenious and genuinely responsive to the needs of society, for the most part it has been superficial and frankly simplistic as regards to products and systems of relationships that certainly must be thought of in the context of a specific history and economy.

2. REGIONALISM AND ARCHITECTURE IN THE CONTEXT OF HISTORY AND TRADITION

The rapid mutation in building typologies, systems of construction that Fathy discussed in his early work, and inherent meanings that architecture has undergone in recent centuries is due to the extensive contact between older established communities and Western colonizers. While myths, community organization, language, and local customs have been largely change resistant, architecture and planning on the other hand have often proved to be quite anxious in rapidly following and adopting theories and approaches coming from distant lands. With little pressure, exotic materials and esoteric building techniques brought in from distant locations have been promptly adopted. Indeed, local architectural traditions seem to be transformed more hastily than the socio cultural context in which they exist. Franchise solutions are ubiquitous worldwide. While one can enjoy exquisite local food in Rabat, Lagos or Rio de Janeiro, the place where one eats is identical in the three rather different geographical locations.

There are several possible explanations as to why architecture has been the Aquilles' heel of both old and new communities. First, early architectural and planning achievements have not been defined exclusively by constructed material objects. In other words, the general population has not been presented with a coherent and easily understood view of their close and distant past. Second, there is a specific attitude toward physical space and its transformation and interpretation. Unfortunately, such attitude in many cases is foreign to the locale and is seldom contested by the local populations. Third, there is a marginal activity (as aspect of what used to be subsumed under the heading of 'material culture,' as distinguished from 'true culture,' the immaterial system of myths, language, system of belief and rules of society) that puts enormous pressure on all the environmental, technological and political decision making processes.

In every community, planning and architecture play a pivotal role that has been in constant change throughout history. A common problem is that many consider these two activities simply as aspects of technology evolution without looking at their relationships to all the issues associated with them. Most history texts only produce a sketch of the history of the community that includes use of building materials and the types of buildings built by them. Few texts and media in general and especially the one produced in less developed societies, simply are not interested nor pay attention to the fact that the architecture of the past has relevance to issues today being faced by our communities. They also fail to recognize the fact that environments derive from specific historical relationships not only *from* the community but *within* the community. In other words, throughout history these solutions have been meaningful only in relation to the totality of the system. And, of course, this fundamental relationship has been broken by the three forces previously described.

If we are to begin a process of reversing these trends, we need to find strategies that address the previous points. And, with regard to the physical manifestations and resulting negative impacts upon the environment, we need to look at the use and their significance in relation to all the groups in contact with it. It is not simply a matter of architectural design. We need to look at every culture and the way it furnishes its own interpretation, attitudes, associations and explanations of *why it is what it is.*

These considerations formed the core of the project that will be presented in the following chapters. In the context of regionalism, the basic premise was that very important clues can be found in the study of the architecture that preceded the current generic approaches to the design of the built environment. And, that the effort should not end as a purely academic exercise but attempt to divulge and propagate the results and findings to the widest audience possible through the use of new digital communication tools and technologies.

The project that will be presented in the next chapters was based on two inseparable aspects: the architecture of historic dwellings, and the architecture of the territory. For both of these viewpoints, the overly simplistic, purely technological approach that typically has resulted in architectural history literature in overvaluing material factors (particularly the local resources) was rejected right at the beginning. Idealistic dialectic discussions of 'man versus nature' were also discarded.

What was then fundamental in the project was that planning and architecture historically played a fundamental role as *political and social* instruments; something very far from today's present conditions where the two disciplines have become almost irrelevant. From this perspective, planning and architecture -in older societies in general and in Mesoamerica in particular- in order to be understood historically and in today's terms, had to be considered in relation to the whole gamut of activities having to do with the comprehension and transformation of space and its interpretation within Mesoamerican societies. In other words, the architectural interpretation of the past had to occur within Mesoamerican society and also had to be considered in relation to other kinds of activity: economic, ritual, mythical, etc. At this point it became clear that the contradiction between physical, architectonic, material structure and cultural and interpretative superstructure was fundamentally tied to matters internal to their society, revealing itself as a contradiction between the real organization of space and systems of construction and the system of interpretation inherent in it. In other words, the foundation of planning and architecture was clearly physical in nature, but its various cultural relationships took over such concrete factors as form, dimensions, materials, and technical solutions. And, this is precisely what has not been occurring today. There are serious disconnects between cultural interactions and the final physical architectural objects.

3. PROJECT STRUCTURE

In order to begin to address the challenges presented in the previous paragraphs, it was decided to undertake the following actions:

1. Consider and select a site deeply rooted in history.
2. Study and analyze the site considering not only its physical form and attributes but its cultural context to the greatest extent possible.
3. Develop strategies that would explain in the clearest terms, how the site was originally laid out, how it grew and how it evolved.
4. Concurrent with the previous task was the linking of design decisions made by the original inhabitants of the site with transformations and evolution of the cultural fabric.
5. Develop visualizations using the latest digital technologies that would present findings in the clearest, most legible and attractive way.
6. Develop strategies so the final visual material would be available to as many individuals as possible. This task included production of materials to be used by different population groups, anywhere from elementary schools to mass media outlets including local and regional television stations.
7. Develop a monitoring system whereby small gains in the public recognition of issues at hand would be recognized.

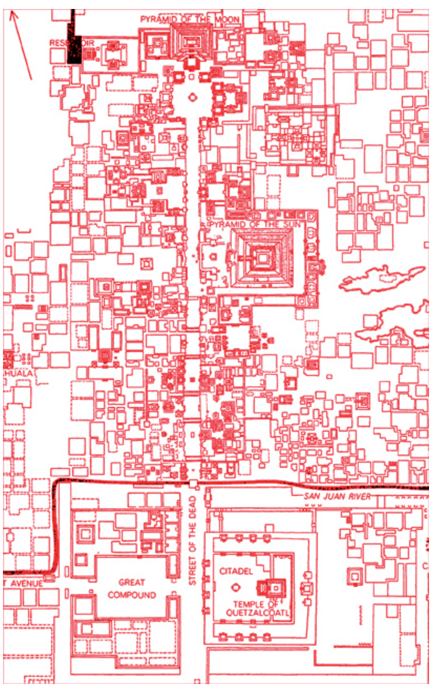

Figure 2: Plan of the central area of Teotihuacan

4. TEOTIHUACAN

The project centered its energies on the ancient Mesoamerican city of Teotihuacan. The reason why this particular site was chosen relates to its powerfully structured world. At Teotihuacan, the designers provided an answer to the question which dogs regionalism and town planning everywhere: restraint or anarchy. The plan of Teotihuacan not only reveals solid environmental choices, but considerable freedom of improvisation, although within the limits set by a wholly consistent structure determined largely by its unique system of construction. The limits are apparent in the principles of the plan and not in any ruling outline which would prevent any form of development. Teotihuacan's plan was dynamic and provided a valuable lesson, for it was based on real organic growth, thus anticipating the most daring solutions of our times by some thousand years.

Teotihuacan was, in the first half of the first millennium, the largest city in the Americas (Coe, 1986). The city reached its zenith between 150 and 450 CE, wielding power and influence comparable to ancient Rome. At its height the city covered over 30 km² and probably housed a population of over 150,000 people, possibly as many as 250,000. Teotihuacan is located in the center of a vast plain surrounded by extinct volcanoes. The early inhabitants of the valley seemed to have dug channels to create an irrigation system and to provide their growing city with water.

When analyzing the plan of this ancient city it is quite clear that for the ancient planners of Teotihuacan every planning and architectural intervention had a meaning and a connection (Miller et al, 1993), something that today's chaotic urban situation sadly misses. Furthermore, the digital mapping effort revealed that planning responded not only to basic physical and social necessities, but that it was also subject to symbolic interpretation - a factor that our current town planning sorely ignores.

5. RESIDENTIAL COMPOUNDS

Due to rather large scale of the ancient city, it was then decided to focus on the residential areas. The architects of Teotihuacan designed residential areas to offer a maximum of privacy within an otherwise crowded city, using a concept similar to the timeless atrium house. The rooms of each residential compound surrounded a central patio; each compound consisted of a series of rooms, patios, porticoes and passageways, all secluded from the general circulation areas of the city. This pattern was also characteristic of the city so-called 'palaces'. To the casual observer the residential areas of Teotihuacan must have presented a somewhat forbidding aspect from the outside; high windowless walls facing on narrow streets. Within the buildings, however, the occupants were probably assured of privacy. Each patio had its own drainage system; each admitted light and air to the surrounding dwellings; each made it possible for the inhabitants to be outdoors yet alone.

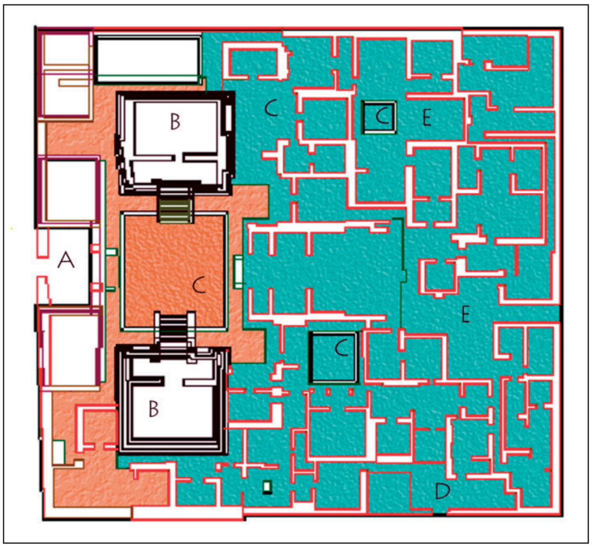

Figure 3: Plan of a Residential Compound

Teotihuacan housing was unique in Mesoamerica and did not have an equivalent anywhere else (Millon et al, 1973, 1976, 1992, 1993). This is because housing in Teotihuacan included a unique multifamily type of configuration in contrast to smaller housing arrangements for fewer individuals as shown in figure 4. From the analysis of several recently excavated sites, it is possible to arrive at the conclusion that housing configurations around the city for the privileged classes was based on a large open patio or courtyard at the same level as the entry. This patio was surrounded by several rooms whose floors were raised above the level of the patio. Many of these rooms had a midwall opening or entry. In all cases, there were other rooms that probably were used for sleeping, storage, and cooking. Because of the particular floor-plan arrangement, it is probable that the roof configuration was flat, with drainage slopes toward the open patio or toward the perimeter, or roofs that were pitched and finished with locally available plant materials. Interior dimensions were of course limited by the ability to span from wall to wall without the use of isolated columns. While it is possible that there were some small openings cut in the walls, for the most part walls did not include large openings.

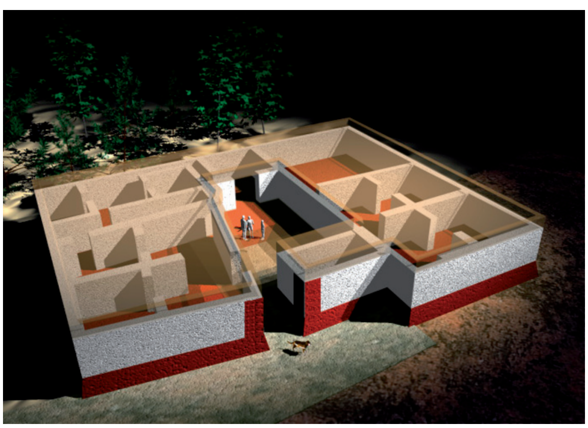

Figure 5: Digital reconstruction of a typical small size compound

At this point it should be pointed out that the previous description matches exceedingly well with what should be done architecturally in this part of the world relative to site appropriation, use of available materials, and most importantly, the excellent fit with the environment – something that current development has sadly ignored. While the original occupants of the site probably did not have the opportunity to 'import' other design solutions, it is clear that they maneuvered in such a way that their solutions fit quite well with both their lifestyle and surrounding environment. It should also be pointed out that several schemes included a main entry courtyard bounded by structures which most likely had religious connotations. Their thicker walls probably implied that those buildings were taller and more important than the other rooms within the compound. The fact that the zoning configuration included mixed uses - residential and religious- within the enclosed compound indicates a very strong relationship between religious practices and everyday living.

The project continued by studying ancient housing typologies in the region and applying results to residential compounds. Many three-dimensional digital models were produced at this time. These were distributed via the Internet to archaeologists and ethnographers who in turn suggested new interpretations and changes to the initial theoretical reconstructions. Because the work was now 3-dimensional, with full tectonic qualities, investigators were now able to visualize data that what up to the beginning of the project was obscure and hard-to-interpret. In other words, new digital visualization allowed for more thorough screening and evaluation of results.

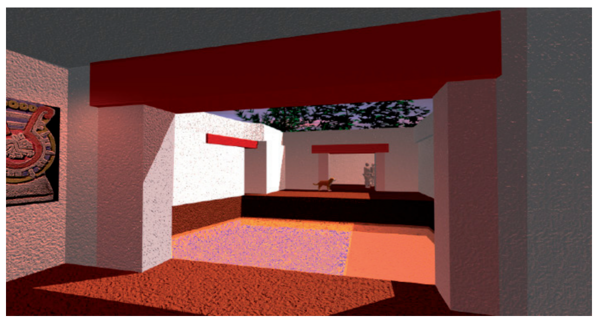

Figure 4: Digital reconstruction of an interior space

What came out of this phase was a fascinating new understanding of not only the superficial qualities of ancient spaces, but an entirely new glimpse of what residential experiences must have been many centuries ago. Moreover, digital visualization allowed for the quick transformation and study of various theoretical positions. Roofs were lifted, walls were repositioned, patios were enlarged or shrunk, building materials were attached and tested, and colors were matched against old Pre-Columbian manuscripts.

Archaeological data also revealed fascinating approaches relative to the very creative use of building materials and technology (Drucker, 1974, Lopez Austin, 1991). At the time of its founding, Teotihuacan construction was of a most elementary nature. With time, the settlers began to acquire more permanent and stronger building materials such as stone, timber, sand, limestone, and large stone blocks quarried for large size sculpture. At first dwellings were built using a mixture of clay, lime, and sand.

More elaborate structures like the first shrines were made of 'tezontle' (a local red volcanic stone) and slate flagstones set in clay. External finishes featured perfectly fitted stones. Steps in staircases were made of pink quarry stone, while the risers were of ‘tezontle’ and clay. Large andesite blocks were used whenever shrines included a talus at their base. Floors in many rooms revealed three layers: first a layer of lime and sand which over time hardened to a concrete quality. Then, several sites have revealed another thick layer of lime-and-clay mortar. The top layer included many variations, from highly polished flagstones to finely ground red-colored clay. Invariably, the central paths that led to some important site featured particularly artistic treatments, sometimes delineated with highly polished stones of various colors or with calcareous limestones.

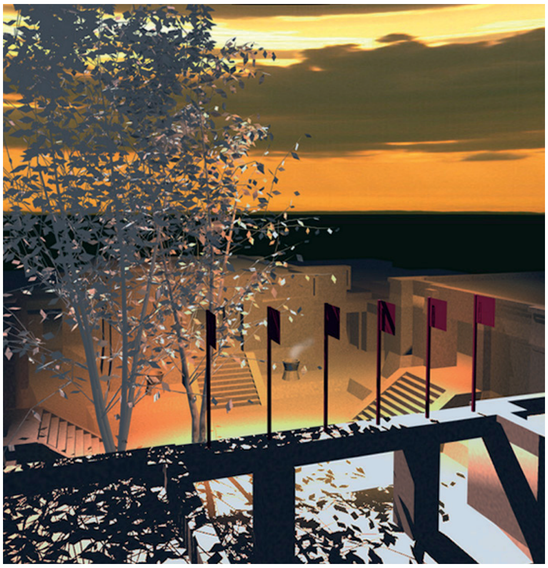

Figure 6: Entry to a residential compound

The previous observations offer more clues to consider in relation to regionalism. First, that the settlers did not ‘import’ foreign schemes or solutions to their building needs. Second that with the fact that they made the best use of what they had at hand. We do not know if the local political organization at the time urged the population to carry out these approaches. However, it is quite clear that there was a general consensus among people living at that time that all kinds of craftsmanship and artisan production were seen with high esteem. Moreover, artistic ways reflected and expressed the identity, originality and peculiarity of the society in which they were produced. Again, this is something that unfortunately has been lost in recent times. Besides, the very strong integration of artisan production to the general building trades most likely contributed positively in term of local economic and social development. Needless to say, but when materials and technologies are imported from other lands these extra positive results simply do not happen.

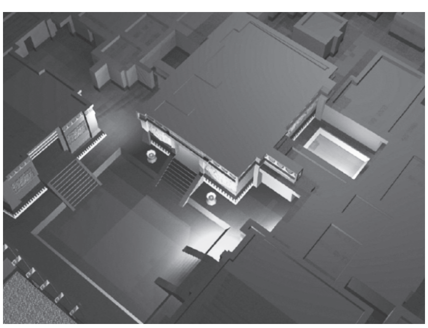

Figure 7: Residential compound at night

6. DIGITAL TOOLS

Digital tools were absolutely essential for the success of the project. Not only these tools brought a new visualization and ‘feeling’ to the final outcome, but greatly facilitated the exchange and ultimate dissemination of results. A critical aspect here was the effect on the general public brought by digital visualization. Instead of looking at some old fashioned low quality graphics, both the general public and specialists were confronted with fresh, highly attractive imagery including night views. Some even labeled them ‘seductive’. A few salient observations in relation to the use of digital tools include:

6.1 Data acquisition

This phase included obtaining reliable and accurate information for the early tentative placement of physical features and existing archaeological elements. The data primarily came from aerial and satellite reconnaissance photography that was scanned and rasterized into digital data. The task was greatly facilitated thanks to high resolution imagery. Items that previously had been mapped incorrectly were easily modified. On site time consuming data acquisition though necessary at some point, was reduced to a minimum due to its high costs. Other technologies such as ground penetrating radar, electromagnetic conductivity and light detection and ranging were considered, but at the end were discarded due to high costs.

6.2 Digital Modeling Process

For the production of the digital models, a drawing database was first set up to include a series of layers. The layers were organized according to archaeological data, dimensional data, historical propositions by various sources, and theoretical reconstructions based on particular issues or topics. A special layer was set for every structure accounted for in the archaeological record and available historical sources. The theoretical propositions began with massing studies based on historical accounts and recent archaeological data and later evolved into more detailed formal investigations. Once the drawing-layer system was set, a basic three-dimensional solids model was constructed that determined the overall dimensions for the most critical parts of residential compounds. The footprint of the residential compounds was based on the most current archaeological data provided by the Mexican Institute of Anthropology and History (INAH). The next step involved adding additional solids to the database to represent:

a) Theoretical reconstructions based on the historical record starting with pre-Conquest codex drawings and the accounts of Spanish chroniclers;
b) Reconstructions of other residential compounds in the immediate vicinity of Teotihuacán and neighbouring states.
c) Theoretical reconstructions base on the work by noted archaeologists, historians and architects;
d) Specialized studies, involving detailed accounts of materials and systems of construction, use of decorative elements, use of artistic techniques in frescoes and pottery.

Once the solid model was completed, it was converted to flat polygonal geometry. This step was taken in order to control with more detail and precision the attachment of texture and photograph maps to individual polygons. The process continued by developing image maps that were attached to the various surfaces. The digital texture maps were based on:

a) Scans of photographs in the historical record, which were then digitally processed to adjust for image quality, brightness, contrast, color, level of detail, and appropriate scaling. Some photographs were carefully retouched to reconstruct missing details. This process involved a 'digital graft process in which existing elements were transplanted to areas where the detail had disappeared or had been mutilated.
b) Photographs taken by the author at the site and surrounding residential compounds. The purpose of these photographs was to develop a series of color texture maps of building materials, construction finishes, colors, and environmental effects such as panoramic views, cloud cover, and distant horizons. The last category of maps was not used for polygon texture mapping but for background mapping. Numerous maps were developed for materials such as tezontle, different types of stones and rocks, and sand. Some reflection maps were produced to simulate environmental maps or scenes reflected on the surface of shiny objects. Opacity maps were generated to specify areas of opacity and transparency. These special maps were used to produce shadow effects in certain buildings and landscape elements. Some surfaced were covered with bump maps to create embossed or bas-relief effects.

The final step involved the initialization of the digital renderer. Due to the very large size of the database, the renderer was set to normal rendering instead of back face rendering. In other words, only those polygons whose vectors or normals pointed outward toward space were rendered. This step was possible because the geometry included very few cases of object transparency. The process continued by selecting an appropriate background for the models. In the case of eye-level perspectives, the background images included photography of actual settings in Mexico. To create a better blend between the foreground and background in regards to the actual model, two types of fog with two different colors were introduced. Near-distance fog was used to soften building edges in close proximity to the digital camera. Far-distance, usually a dark blue, was used to blend buildings in the distance with the mapped background. Both types of fog were applied selectively by adjusting relative percentages. The sampling was generally set at 1:1. Shadows were set simultaneously by volume and by ray tracing, depending on each individual light. In the case of shadow maps, the size was set at 512 for higher quality definition using a factor of between 6 and 10 volumes. The smoothing angle was set to 45 degrees, which meant that angles less than 45 degrees were smoothed and angles greater than 45 were considered edges. No antialiasing was used for images with large volumes and little detail, and high antialiasing was used when the images had considerable detail. The minimum depth shadow controls were set to 2 for minimum bias and 4 for maximum bias. All images were rendered at 2600 by 1280 pixels at 24 bits per pixel and were recorded in a Tagged files File format (TIFF).
Finally, the system used involved the use of several computers with multi-processors capabilities running at 2.5 Ghz and higher speeds.

6.3 Data correlation

The project included the digital correlation of older studies with new maps and data obtained through high altitude satellite reconnaissance. Again, this task was greatly facilitated through the use of computer assisted design applications allowing multiple drawing layers to be combined in a variety of forms and configurations. Older drawings and maps were also digitized in order to manipulate their scales and individual attributes such as building textures, colors or other identifying features.

6.4 Data sharing

An aspect that proved invaluable, especially during the early phases of the project was the ability to quickly share preliminary results with other investigators currently working on the project as well as researchers that had conducted similar studies in the past. Data sharing not only included specialized scientific research teams, but local citizens with little schooling and/or expertise as well. All of this was greatly facilitated by the use of the Internet, e-mail and file transfer protocols. A number of people were asked to make comments and notes on the preliminary findings. Many responded accordingly with a variety of suggestions ranging from very sharp criticism to pointing out to other potential sources of data and information. Discussions were held to absorb all the new data in further iterations of the project.

6.5 Visualization

Digital visualization was perhaps the most successful part of the project. Not only digital imagery allowed for closer scrutiny of potential ancient site reconstruction, but most important, it allowed for excellent communication between all parties involved, from the experts, to people of all ages and social strata. The fresh imagery that came out of each phase of the project brought to a new level of understanding the accomplishments of past generations that heretofore had been the privilege of an elite class of research professionals. It also sparked a renewed enthusiasm in common people that had never thought their ancestors were capable of great accomplishments.

6.6 Dissemination of results

"Sometimes the magnitude of the problem has created in me a state of desperation, and it seems that this malignant and irreversible operation (the generic approach to environmental design) of destiny does not have a solution. I have succumbed to a feeling of impotence, sadness, and pain in relation to what has been happening to my countrymen and my country.' As pessimistic these words may be, Fathy quickly came up with an inspired message followed by a call to action. What he said is essential. *If we are to begin to reverse the trends brought by the current ubiquitous generic approach to the design of the built environment, we need to help those individuals that are very much aware of the state of cultural confusion and want to find remedies to the situation.* As Fathy noted …'cultural decadence begins with the individual, who is presented with alternatives which he (or she) does not know how to pick; this is where we should begin'. In the spirit of such wise advice, the project developed a variety of digital visualizations, simulations, and diagrams accompanied by concise text with the ultimate goal of reaching those individuals and groups concerned about the problem all while offering them the tools to make better and more informed decisions about the built environment based on the many generations of creative minds that preceded them.

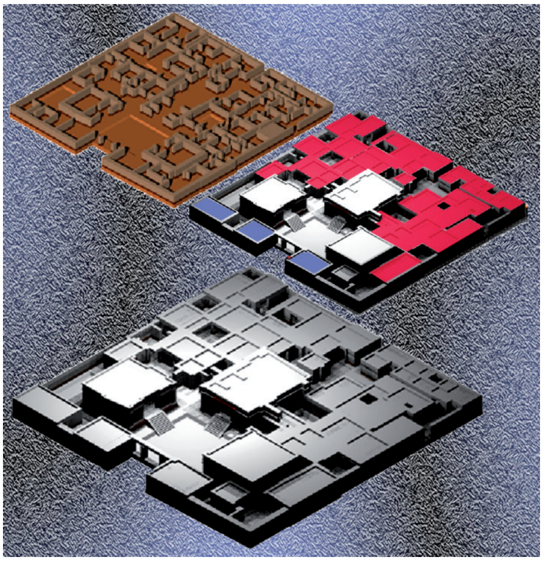

Figure 8: Layering data example

7. RECORDING, PUBLISHING AND DISSEMINATION OF RESULTS

In this phase, digital media and associated technologies proved invaluable too. The following lists a few strategies:

1. All data that the project dealt with was basically digital. This applied throughout the project, from its inception to the final stages. Older texts, manuscripts, diagrams, maps, sketches and the like were scanned and if needed rasterized. This includes recent work by Saburo Sugiyama, noted archaeologist (Sugiyama, 1989 – 1995). When applicable, data files were sent to appropriate parties including the media and research interests for further study.
2. The project emphasized the search for new and attractive ways to visualize information. Whenever possible or applicable, texts were 'translated' into some dazzling graphic form. Older, unattractive or otherwise non legible maps or three-dimensional forms of representation were converted to the most eye-catching, easy to understand visualization. This particular action included, for example, correction of older perspectives and sketches and more accurate definition of the real dimensional qualities and proportions of older structures. This action not only updated what had been known, but also corrected a number of misconceptions and errors made by the historical record.
3. Publication of findings was done electronically; there were no paper-related expenses associated to pre-printing tasks. Considerable economies resulted from this action.
4. In addition to traditional printing of findings, summaries with selected topics were made available in the form of brochures. Libraries, social and political groups were also made aware of the project. Many received free copies of the final publications. Radio interviews were broadcasted. Results were also made available to the general public through the Internet on dedicated web pages.

8. FINAL NOTES AND CONCLUSIONS

What the final phase clearly demonstrated is that digital tools can greatly further the cause of regionalism and associated goals. Before the advent of digital tools and communication technologies, results of projects like this one would have been rather limited. The fallout today is much more promising. So far the following has been noted:

1. The general public is more aware of the great contributions of the many generations that came before us.
2. The same public can now easily visualize how conditions existed before current globalization trends. The value of preserving and enhancing rich cultural patrimonies comes to the foreground in a more significant way.
3. By digitally visualizing before-and-after conditions the general public is more informed about ecological disasters and loss of cultural patrimony.

The project has received widespread attention. A quick survey on Internet links reveals an ever increasing series of articles based on the original project. Varied and diverse institutions and publications such as the Metropolitan Museum of Art, The British Museum and Arqueologia Mexicana have dedicated issues on the topic. At the local level small communities in the proximity of Teotihuacan are now part of a consolidated improvement plan and operation facelifts have been started. There is now a flood of publications clamouring for further action. What once was a rather silent issue has become a roaring proposition (www.urban-age.net).

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AN INTEGRATED ENVIRONMENT OF REPRESENTING DIGITAL ANTIQUES

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KEY WORDS: Virtual Reality, Augmented Reality, integrated virtual environment, interactive exhibition, RFID

ABSTRACT:

The well-developed technologies of 3D scanning are wildly utilized in documenting 3-dimentional physical objects effortlessly. Therefore, some advanced technologies and software are designed for creating digital 3-dimentional data, mapping textures, and even simulating real texture for virtual environment. However, after documenting and simulating these real artefacts in virtual environment, what kind of the virtual environment is suitable for representing these 3D digital objects and interacting with visitors in exhibitions. Therefore, this research will propose an interactive virtual reality (VR) environment for demonstrating virtual objects by operating some interactive hardware, such as RFID. In doing so, people could interact with the 3D virtual sculptures in an interactive environment.

1. INTRODUCTION

The museums, such as scientific museum, art museum, zoo, botanical garden…etc., are some kinds of unofficial educational institutions, which provide places not only for documenting art works, but also for educating people by regular exhibitions. Usually, in these exhibitions, visual display, like panel, text description...etc., is a common media for presenting historical relics and masterpieces. By reading information from 2D panels, visitors could realize the aesthetic and historical values of antiques or artworks during their shortly staying in museum. In museums, however, the collections of cultural heritages are immense, and interests of visitors and their viewing experiences are not identical. Moreover, from the viewpoint of learning effect, there are two limitations of visiting physical museums. The first is the opening time, which is limited for finding people's interesting target and understanding them, while the second is the "museum fatigue". After long staying in museum, the "museum fatigue", which pointed by Benjamin Gilman (1916), will dramatically decrease the learning efficiency from visiting art works. In order to reduce the museum fatigue, there are some electronic devices helping visitors to understand more on artworks, such as electronic language descriptions. Compared to traditional tour guide and panel descriptions, the benefits of using electronic language descriptions are not only fetching up the shortage of tour guides, but also enhancing people's interests during their staying in museums.

Although the electronic language device could provide several channels, such language, video…etc., to descript history or story of artworks in exhibitions, there is another difficulty for visitors when using the complicated interface (Rieber, 1994). Visitors have to be trained for utilizing a new interface during their staying in exhibitions; otherwise, an unfriendly interface of the electronic language will lose not only visitors' patients of using the interface, but also their interests of the contents in museums.

Based on those problems, mentioned above, the objective of this research is not only to help visitors to efficiently select appreciate subjects, based on their interests, but also to construct an interface in which users could operate, view, and learn from the artworks in virtual environment. By doing so, this study will build up a virtual environment for demonstrating sculptures of Mr. POO TIEN-SENG, who was a famous sculptor in the early Taiwan art history. In this environment, visitors can view and operate these 3D-scanned and texture-mapped sculptures by RFID, and learn the information of sculptures in the interactive interface.

2. RELATED WORKS

There are some related studies, which provided the background and technologies for this project, including traditional exhibition, computed and virtual display, the technology of interactive interface, and tangible user interface (TUI).

2.1 Traditional exhibition

There are different types of museums, depended on divergent purposes and contents, such as historic buildings, science, technology, and nature centres, aquariums, zoos, botanical gardens, and traditional, historic, and natural history museums. The collections of these museums may include paintings, literatures, sculptures, buildings and historic relics. The traditional exhibitions are utilizing panel descriptions to illustrate the contents for visitors, but the static descriptions are not good ways to arise visitors' interests. Therefore, some exhibitions attempt to apply new approaches, such as expositions, guides, sound, and video guide (pda and headphone guide). However, there are different abilities of using these devices among visitors (Randy Korn & Associates, 2006).

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Moreover, during the visiting process, people usually receive plenty of information, such as the years, locations and styles, and they have to spend much for reading, comprehending, and remembering all information. Therefore, They gradually have mental burden after gathering much information from various kinds of exhibiting media in museums. According to Benjamin Gilman (1916), that is called "museum fatigue", which means that after visiting a number of exhibitions, people will feel tired, and the process of visiting will be reduced in next viewing of exhibition. Arthur Melton (1935) also suggested that visitors should spend more time to visit the front halls instead of the back halls. It demonstrates that visitors' interests and psychological status would be influenced by the information of the exhibits during the visiting of museums.

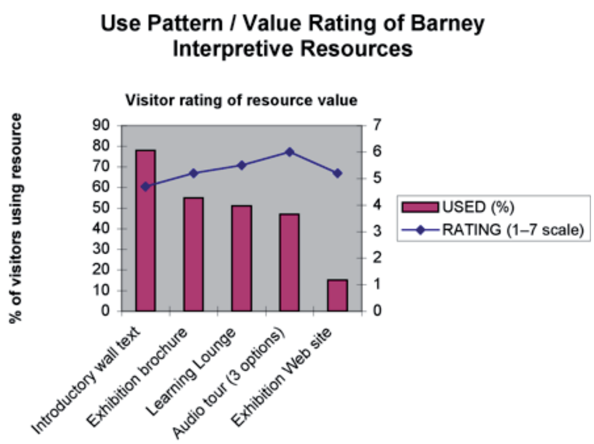

Figure 1: Use Pattern/Value Rating of Barney Interpretive Resources (after Randy Korn & Associates, 2006)

By reading the descriptions in traditional exhibitions, visitors can receive the information passively instead of actively filtering the information; some museums arrange the exhibits and design regularly with the paths planned. These static exhibitions cannot significantly enhance learning and interest and reduce the fatigue of visiting. The reason is in that there is only unilateral communication between static descriptions and figures.

Only dynamic forms lead to actual interaction between the users and the exhibits. Thus, the dynamic "operation" can enhance the reality. In other words, the visitors operate the descriptions of exhibition and look for the questions and answers. Sandifer (2003) indicated that comparing with small-scale and static exhibitions, large-scale and dynamic ones tend to enhance the visitors' vitality in the exhibitions. The study of Blud (1990) on Science Museum of London probed into parent-children relationship in the museums, including interactive, touch and static exhibitions. The results showed that different patterns would result in different interactions among the visitors.

The relationship between various description measures of display and user communication refers to "Interactive Experience" in Museology, (Museum Studies). In traditional displays, the communication between the operation and the users is limited. Borun (2003) suggested that compared with traditional display, the interactive display tends to attract the visitors and enhance their vitality. The interactive display pattern would further influence the visitors' visiting time in the museums (Kropf, 1989). Thus, the interactive exhibition would enhance the visitors' interests in the display content; moreover, the visitors can freely select their exhibits to further accomplish their learning.

2.2 Computer simulated and virtual display

With the progress of computer technology, computers not only can simulate the real objects after digitalized, but also can display them via Virtual Reality and Augmented Reality. Howard Rheingold (1991) defined Virtual Reality as a kind of experience to be surrounded by 3D computer graphic environment. Users can freely walk, change their vision, grasp the objects or change the patterns; on the other hand, Augmented Reality means to produce 3D images by the image identification of the computers. The materials of 3D images can be changed and modified to further be combined with real space and overlay realistic and virtual images (Figure 2) (Huang & wang, 2008).

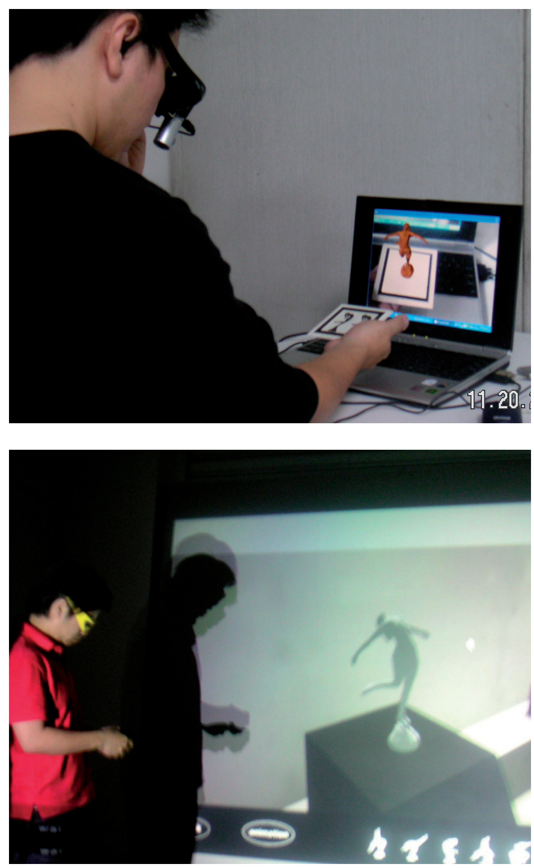

Figure 2: Up: the exhibitions of Augmented Reality; Down: the exhibitions of Virtual Reality (Huang & Wang, 2008)

Virtual Reality includes realistic and virtual space: the reality where the users exist and the virtual space. Users control the objects in virtual space by the interface (3D glasses, controller and bottom) in real space. Virtual space consists of the space, light, color and sound effects and it simulates the scenarios in reality. Its interaction with the users is to allow the users to "indirectly" influence the virtual space by various forms and interfaces. With regard to the characteristics of Virtual Reality suggested by Giganta from the perspective of techniques and the objects and operation in virtual space, such as 3D images, 3D vision and virtual space preview. In Virtual Reality, the users would have the illusion of real participation and it is the penetrated experience with multiple sensory stimulations (Burdea and Coiffet, 2003).

As suggested by Aukstakalnis and Blatner, Virtual Reality is a kind of complicated innovative concept with technology integration and it focuses on interactive 3D environment produced by the computers. The users can completely involve in and use the virtual space (Vallno, 1998). In order to fulfill the above, Virtual Reality must integrate internal software, multimedia program and external devices and interfaces to lead to complete simulation. With such plenty of integration, the devices of Virtual Reality are more than other simulation and multimedia.

The similarity between Augmented Reality and Virtual Reality is that they both involve real and virtual space which is connected by interactive interface (device); comparing with Virtual Reality, Augmented Reality emphasizes real space and it creates virtual objects in real places and enhances the information display and interactive experience in the real world. The earliest Augmented Reality was in 1960 when Ivan Sutherland et al. constructed 3D head monitor with mechanical tracking. By wearing this device, the users could see the information produced by the computers and real objects projected on the wall which leads to the illusion of virtual objects in real places (Sutherland, 1968).

According to few institutions from 1980 to 1990, Augmented Reality means "the transparent monitor worn by the users on the heads. Thus, it can directly combine the real places and images produced by computers. Basically, it is a kind of special Virtual Reality (Milgram, Rakemura, Utsumi and Kishino, 1994). The percentage of real and virtual space in Augmented Reality will influence the meaning of the device. When there are more "real" elements, it is called "Augmented Reality". In other words, the users could see both virtual space in real places and real objects in virtual space (Milgram et al., 1994).

The three characteristics of Augmented Reality (Azuma, 1997) are: combination of virtual and real space, immediate interaction and 3D environment. There are different actual operations with regard to different demands such as reading 3D projection cards and 3D labyrinth in daily lives and projection of direction on the unfamiliar roads. New interactive experience is involved in daily environment.

Comparing with Virtual Reality, Augmented Reality saves the time and space to construct virtual scenes. It combines virtual objects in the users' environment. With regard to devices, it can involve several projectors, Readers, head monitors and video cameras to receive the users' controlled figures and project it by 3D through Reader or control interface. Thus, the users can freely walk and have interaction instead of simply sitting in front of the computers to image the flats as 3D world.

With the virtual display, "Interactive Experience" of the museums can be enhanced. Borun(2003) found that comparing with traditional exhibition, the interactive display is more attractive to the visitors and it can enhance the audience's vitality. By "operate", dynamic display could enhance the reality with "feedback". Thus, there is real interaction between the users and objects. Sandifer (2003) also suggested that comparing with small-scale static exhibition, large-scale dynamic display can further strengthen the visitors' vitality when visiting the exhibitions. Comparing with traditional exhibition, virtual exhibition can break through the past obstacles, such as turning the exhibits or seeing the detail parts.

2.3 The technology of interactive interface

In the field of information, "interface" means that upon the connection between software and device, intermediary operates or interacts with the computers. It is called user interface (Houston, 1992). Broadly speaking, it is the message, information or symbol in the interaction between computers and users (Jones, 1993). Powell (1990) suggested that user interface refers to the communication between the programs and users. In other words, user interface is the media between human beings and computers.

However, in the museums, users have different backgrounds and demands, and thus they would intend to obtain different information from the same object. For good user interface, the time spent on learning operation must be reduced to avoid the users' impatience. The display should be diverse and selective to be flexible for the users. As mentioned above, the individuals' learning would only be enhanced by the things, which will maintain or enhance them. It indicates that user interface should change according to the individuals' different demands.

The information processing of these interfaces is circular, and presented by operation. Generally speaking, operation of user interface includes input and output. For instance, keyboards and mice of the computers are input devices whereas monitors are output ones (Figure 3). Interface refers to intangible interaction and it is "intermediary" which connects the users, people and objects.

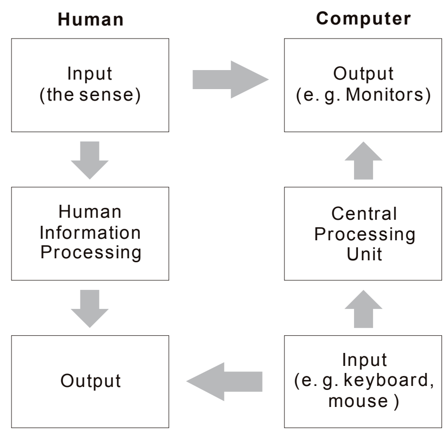

Figure 3: The Process of Interface Information

In the exhibitions of the museums, user interface (such as voice guide, multimedia display booth and descriptions on the walls) is the communication between the visitors and the exhibits. By various explanation measures, the users would acquire valuable visiting experience (authentic interaction: the visitors are the rebirth of the creators) by active learning. However, the operation of display interface should be more diverse. Biosvert and Slez (1994) suggested that with the display upon more selections, all levels of the visitors would recognize the exhibits interesting them.

With regard to the display of interaction interface, besides the focus on virtual exhibition, the study can also target on how the users will instinctively operate the interface; reader is required to detect the users' actions and intentions. Reader involves various forms, and it detects the change in the surround and sends the figures back to the computers to drive other effects. Thus, it should be based on three basic elements: sensation, drive and control. For instance, the smart space in modern time involves many Readers to detect people's positions or movement in the space. However, these Readers only sense the light, heat or sound instead of specific objects to further distinguish them.

Another kind of reader for distinguishing different objects is Radio Frequency Identification (RFID). It launches radio waves by Reader to sense RFID Tag in the scope and further produces electric current by electromagnetic induction, support the operation of chip on RFID Tag and respond to Reader by electromagnetic wave. RFID Tag includes active and passive types: passive Tag does not involve battery device and the electric current is produced by radio waves of Reader. Thus, Tag passively responds to Reader after receiving the signal sent by Reader, active Tag involves battery and it can actively send the signal for Reader and the transmission scope is broader. The application in daily lives includes domestic control system, convenience store and department store system and Electronic Wallet. In museums, it is applied to object management and PDA and RFID display. The advantages are small, light and portable. This study aimed to combine the display of Virtual Reality and RFID Reader to allow the users to select the exhibits and appreciate and learn from the exhibits by instinctive operation.

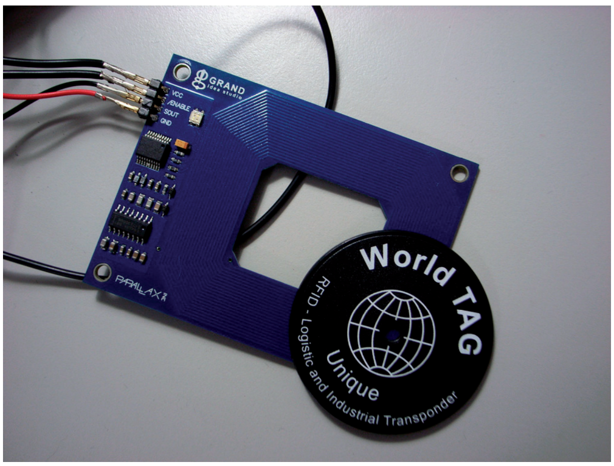

Figure 4: RFID reader and Tags

2.4 Tangible User Interface, TUI

The tangible user interface (TUI) extends the benefits of Graphic User Interface (GUI) to emphasize the interaction between users and interface. In order to obtain the instant feedback from users, there are several physical hardware or devices to detect human behaviours during the interacting with the interface. The design of interface, proposed by Ishii in 1997, is that the combinations between human bodies and interaction systems to archive more intuitive operations. Moreover, Ullmer, Ishii and Jacob (2005) addressed two fundamental elements in the physical computing interface. The first is the physical device, which is the interface for manipulating digital data or information in computerized media; the second is virtual system for representing virtual objects, which will be operated by the physical devices. Thus, the TUI will connect physical human behaviour to digital information between physical and virtual environment. In this TUI environment, people could interact with digital objects or environments intuitively by their native behaviours (Arroyo, Bonanni, and Selker, 2005). For instance, the project of iSphere, shown in Figure 5, is a physical 12-face sphere, which has sensors responding to the positions of fingers and operating by hands. The input sensing devices of iSphere are the capacitance to detect the distances between human hands and face of iSphere. By detecting the distance from 1 to 6 inches, the sensor will recognize as pulling; on contrary, the distance from 6 to 1 inch will be regard as pushing. Moreover, it will be detected as pressing when the distance is less than 1 inch. By doing so, people could transform a 3D digital model in virtual environment by controlling the distances between hands and capacitance sensors (Lee, Hu, and Selker, 2006).

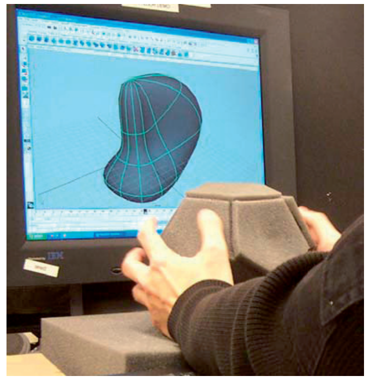

Figure 5: The iSphere project (after Lee, Hu, and Selker, 2006)

3. THE NEW RFID INTERFACE OF REPRESENTING 3D DIGITAL SCULPTURES

The reduction of the users' interest during the process of visiting is significantly related to their visiting behavior. Falj & Balling (1982) suggested that proper new places could excite the people and enhance the interest in the visiting. Thus, in order to increase the users' interest in appreciating the exhibits in the museums and the interaction, this study constructs an interactive exhibition environment combining RFID and Virtual Reality. In this environment, the visitors can select the years, series and materials of the exhibits by RFID to treat these three categories as individual objects. Thus, the visitors could interact with the information and exhibits they are interested in when visiting the exhibitions.

3.1 The hardware

The interface, shown in Figure 6, is to install RFID Reader on the specific area of the display and arrange RFID TAG in the description category on the left of the display. The users select the years, series or materials they are interested in; RFID TAG is placed in the area of RFID Reader; the signal received by RFID Reader is sent back to the computers by Arduino chip; the exhibits in database is filtered and the exhibits selected are projected to the display. Thus, users can select the exhibits for watching or further filter the exhibits by RFID TAG; users finally filter the qualified objects in the interesting category and the interface images are projected to the display by the projector. Thus, users can obtain the descriptions in detail and interactive exhibition. The framework of this interface is illustrated in figure 6, included a projector, a set of ARDUINO chip, several RFID readers, and RFID tags, which represent different attributes of sculptures.

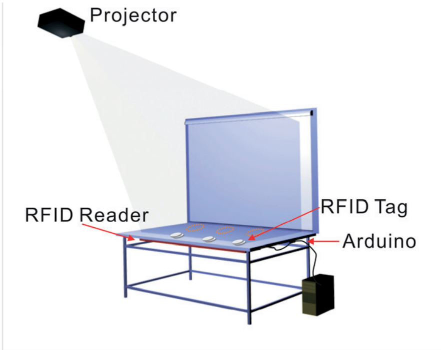

Figure 6: The Framework of the hardware

3.2 The Tags

There are three types of RFID tags, which are representing years, materials, and serials, respectively, shown in Figure 7.

Figure 7: The tags for representing three attributes of sculptures

3.3 The 3D environments of virtual antiques

In this project, we not only create a RFID interface, but also connect to 3D virtual environment, which conducted by Virtools 4.0 (shown in Figure), for representing digitalized antiques/sculptures. In this interface, people could utilize different sorts of RFID tags to choose their interested year or material or serial, respectively.

The tags, detected by Arduino chip, will be transmitted into the Virtools environment. Therefore, the sculptures, which satisfied the attributes from tags, will be demonstrated in the virtual platform.

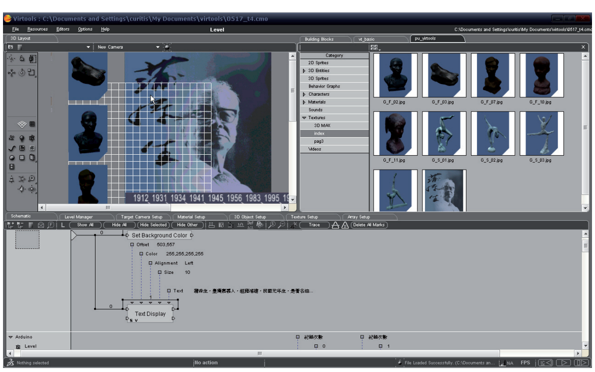

Figure 8: The Virtools environment for conducting the platform

4. THE DEMONSTRATION OF REPRESENTING DIGITAL SCULPTURES

This project is supported by "The digitalization project of POO TIEN-SENG in early period of Taiwan sculpture history", in which we could obtain some digital sculptures, and represent them in this demonstration. Thus, the following section is about the subject of the sculptures, and then the final demonstration of this environment.

4.1 Subject of interface

The subject of the interface is "Mr. POO TIEN-SENG", who was a famous sculptor in early stage of Taiwan history. He was born in 1912, and died in 1996. His life dedicated to sculpture, and awarded by his distinctive sculpture style. In order to describe his considerable sculptures, there are categorized into three attributes: year, series, and material. The first attribute, year, is ranged from 1941 to 1996. The series are including four sets of sculptures: family, people, animal, and sport. The third attribute is using of material in his works, included bronze, fiberglass (FRP), and clay. Two sculptures made by bronze, shown in figure 9.

Figure 9: Sculptures of Mr. POO TIEN-SENG

4.2 The process of demonstration

The aim of this research is to construct an intuitive interface by which visitors could search and browse their interesting sculptures, and interact with them intuitively. Therefore, the real environment, illustrated in figure 10, is a "L-shape" table, projected by a projector. The upper part of this environment shows the information of sculptures, while surface of the table shows the interface of operational information. In the upper part, several sculptures are stored in different sheet in virtual world. On the down part, there is the input interface, which guide users to determine their interests among years, series, and materials.

The process of the demonstration are followed:

1) RFID interface: some information will show on top of the table to indicate what information user should choose and input the RFID tag in the area of table. The interface will indicate the years, series, and materials, respectively or randomly.
2) Sculpture demonstration: after inputting more than two attributes of RFID tags, users could narrow down their interests of considerable sculpture, and finally, inspect their interested outcomes on the upper part of environment.

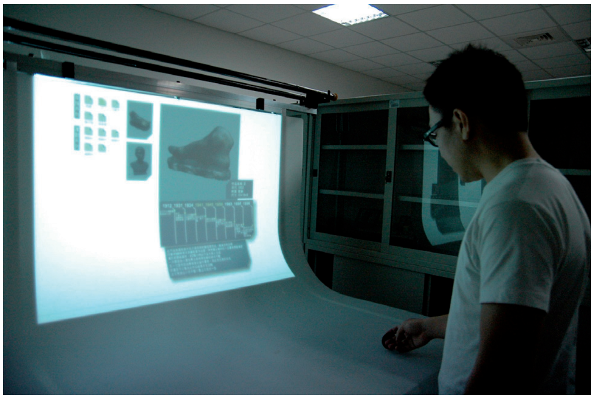

Figure 10: The demonstration of interface

5. CONCLUSIONS

The results of this study indicated that the years, series and materials of the exhibits are the information people intend to acquire with regard to this exhibition. In the museums, the years are usually introduced in the description; as to the category of sculptures, the visitors sometimes are not allowed to touch them and thus, the materials of the exhibits are usually introduced. The sculptors selected in this study create different works in different periods and thus, this study classifies the works by different series.

In the process of the experiment, this study realizes that comparing with traditional exhibition models, RFID interface system can increase the users' interest and their staying time. The system can avoid the users' fatigue when reading traditional descriptions. When users search for the answers to the questions, they could clearly recognize the fact, and their memory would be enhanced after appreciating the works. As to the operation, they can immediately learn the use with their instinct to operate the system more naturally. In the future, this study intends to develop contactless interface based on this kind of contact display interface, which is not the touch screen in modern time. The aim is to allow the users to operate the system by instinct, produce the feedback during the visiting and reduce the objects needed to reduce the burden.

ACKNOWLEDGEMENT

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A COMBINED STATISTICAL AND RULE-BASED GENERATIVE MODEL FOR THE REPRESENTATION OF FACES IN CULTURAL HERITAGE ARTEFACTS

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KEY WORDS: Generative Face Models, Statistical Face Models, Byzantine Style, 3D Reconstruction, Restoration

ABSTRACT:

The abilities of testing the authenticity of Cultural Heritage (CH) artefacts along with the abilities of digital reproduction and digital restoration constitute key actions that can significantly contribute towards the preservation, exploration and dissemination of CH. However, in order to deal with the tasks mentioned above, it is necessary to develop techniques for faithful digital reproduction that incorporate design styles associated to the artefacts in question. In this paper we present a methodology that can be used for augmenting statistical appearance models with a set of design rules, allowing in that way the generation of models specific to a certain design style. In our preliminary work in this area we focus our attention on the generation of customized statistical models that adopt the Byzantine style. In this context a set of geometrical rules are incorporated in a generic statistical 3D face model representing human faces, allowing in that way the generation of a Byzantine style specific 3D face model. The ability of the model developed to generate faces consistent with Byzantine rules is tested both using a quantitative and visual evaluation; the results obtained prove the potential of the proposed approach.

1. INTRODUCTION

The availability of methodologies capable of reproducing artefacts belonging to a specific style can have numerous applications related to the field of Cultural Heritage (CH) preservation. For example such technology can be used in the following related applications:

(1) Digital reproduction of novel artefacts: The ability to produce faithful digital reproductions of artefacts belonging to a certain style ensures that the style in question will be preserved, even in the case that original artefacts suffer damages. Along these lines digital reproduction of 3D artefacts enables the replication of artefacts and the generation of novel instances of artefacts that adopt styles consistent with the original so that it is possible to incorporate such digital reproductions in educational software, virtual environments and other multimedia productions that support the dissemination of CH related information

(2) Restoration of damaged artefacts: CH artefacts often suffer damages caused either by natural causes (i.e. weather, earthquakes etc) or by deliberate acts of humans. In such cases it is desirable to restore artefacts in the original state, either using physical restoration techniques or based on virtual restoration that creates digital replicas of the restored items leaving the original unaffected (Petzet, 2004; Callieri, 2004). Due to the danger of causing irreversible damage to the original, virtual restoration is gaining increased popularity. The process of restoration requires detailed knowledge of the design style of an artefact, so that given partial information and the associated design rules it is possible to generate a feasible prediction of the appearance of the damaged area. The method reported in this paper aims to incorporate design rules related to the style of artefacts in a generative model, hence the resulting model could be used as the basis of implementing digital restoration techniques.

(3) Authenticity tests: Automated authenticity tests are useful in CH related studies, as they allow the identification of artefacts that do not comply with the style of items belonging to a certain artistic group. The method reported in this paper could be utilized for developing automatic authenticity tests. In this context the appearance of an artefact can be tested in order to determine whether the given artefact presents a plausible instance of a statistical model that incorporates relevant design rules, allowing in that way the derivation of conclusions related to the authenticity of the item.

(4) Auto-training: The proposed framework could be used for developing interactive e-training applications for new designers. In this context a system utilising rule-based generative models could be used for correcting or complementing the design efforts of new trainees during e-training processes. Training new designers to generate artefacts belonging to a certain design style poses one of the most effective ways to ensure that a design style is preserved.

Dealing with the type of applications mentioned above requires the availability of techniques that learn about the design styles of different artefacts and apply the styles during the application of reproduction, restoration, authenticity tests and e-training. Preferably methods for modelling design styles should be combined with an engine that allows the generation of novel instances that comply with the design rules. An important aspect of style-specific generative models is the ability to generate virtual 3D artefacts, so that the use of digitally reproduced artefacts in 3D environments is supported.

With our work we aim to address the problem of building generative 3D appearance models for different types of artefacts. Such models incorporate design constraints associated with certain class of artefacts allowing in that way the faithful reproduction of novel instances of artefacts exhibiting the desired style, the restoration of damaged artefacts and authenticity valuation tasks. As part of our preliminary work in this area, we concentrate on the development of techniques for building generative 3D models of facial appearance customized to different styles. In our pilot study we have chosen to deal with face models since in a significant number of cultural heritage artefacts, human faces enjoy the focus of attention both during the creation and exhibition stage. Typical types of artefacts where the human face is considered as a central item among a synthesis include paintings, statues, wall paintings and anaglyphs. Usually faces appearing in such artefacts are generated based on certain rules that reflect either the personal style of the artist or the style defined in different cultures and time periods.

More specifically in this paper we deal with the development of a statistical rule-based model that incorporates design rules associated with Byzantine faces appearing in icons. For this preliminary investigation we opted to focus our attention on Byzantine faces since sets of concrete geometrical and chromatic rules that define the appearance of Byzantine faces are available in the literature (Vranos, 2001; Kontoglou, 1960; Byzantine Style, 2010).

The proposed approach for generating appearance models incorporating dedicated stylistic designs of human faces is outlined in figure 1. The first step involves the generation of a statistical 3D appearance model representing 3D human faces. The second step involves the definition of a number of constraints associated with the required design style and the formulation of methods that allow the calculation of the level of compliance of a given face shape with the design rules. In the third step a large number of novel instances of faces are generated and each instance is assessed against the geometrical constraints so that the set of instances that comply with the design rules are isolated. The last part involves the generation of a new model based only on the synthetic training samples that comply with the pre-specified rules so that the resulting model is specific to faces exhibiting the desired style. The Byzantine style specific model developed as part of our pilot study was evaluated based on both a quantitative and visual tests. The results obtained form both tests demonstrate the potential of the proposed method in building style-specific statistical face models. To the best of our knowledge the generation of customised appearance models incorporating design rules was not addressed so far in the literature.

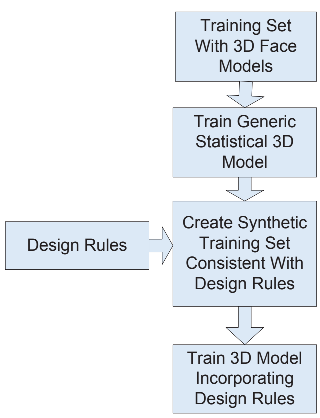

Figure 1: Block diagram of the proposed methodology for training statistical models incorporating design rules

The remainder of the paper is structured as follows: In section 2 a brief literature review of relevant topics are presented. In section 3 a brief history of Byzantine art and major design rules for Byzantine faces are outlined. The method for generating style-specific generative appearance face models and the results of the experimental evaluation are described in section 4. Conclusions and plans for future work are presented in section 5.

2. LITERATURE REVIEW

The idea of developing computer algorithms for producing drawings that follow certain design-rules originates back to the work of Yessios (Yessios, 1979) and Stiny and Gips (Stiny, 1972). Yessios (Yessios, 1979) presents algorithms for generating design patterns that exhibit random structures. In this context an algorithm that introduces random alterations to regular patterns is implemented, so that it is possible to produce realistic textures representing plants, wood patterns, stones and ground materials. The work reported by Yessios (Yessios, 1979) relates to the work described in this paper as both papers attempt to develop techniques that mimic the drawing capabilities of human artists. However, Yessios deals with the problem of generating realistic random structures whereas in the work described in this paper the problem of automated drawing based on concrete geometrical rules is considered.

Stiny and Gips (Stiny, 1972) introduce the idea of generating paintings based on shape grammars. Shape grammars define a set of shape primitives and rules that specify how these shape primitives are combined in order to generate paintings. The proposed automated design process involves the definition of a starting shape primitive and the incremental combination of additional shape primitives based on the grammar rules, enabling in that way the construction of aesthetically pleasing patterns. The work of Stiny and Gips (Stiny, 1972) refers to the design of non-representational art objects in a way that emulates the design process adopted by artists. Although the work described by Stiny and Gips (Stiny, 1972) resembles similarities to the method described in this paper, both the method adopted and the ultimate task display significant differences as in our work we propose a holistic design approach that produces integrated shapes that comply with design rules whereas Stiny and Gips adopt a bottom up approach where a shape is drawn iteratively by combining shape primitives.

The method described in this paper relies on generating face shapes based on statistical face models. Statistical face models (Cootes, 2001; Blanz, 1999) have been used extensively in a number of applications involving face image processing. 2D and 3D statistical models are usually generated based on a training set containing 2D face images or 3D laser scanned faces respectively. In the case of 2D modes all training samples need to be marked up with a number of landmarks resulting in a laborious and time consuming task. In the case of generating 3D face models it is necessary to go through the time consuming process of 3D scanning an adequate number of samples. Due to the need for 3D samples during the generation of 3D statistical models, the standard training process for generating 3D statistical models can only be applied in cases involving 3D items (i.e faces of statues or human faces) but cannot be applied for modelling 2D objects such as faces in paintings. In an attempt to deal with issues mentioned above we propose the development of a rule-based statistical model that uses an existing training set as the basis for training a generic model, but augments the model with constraints associated with the design style we wish to model. The proposed method eliminates the need for going through the time consuming process of generating manually training sets for different styles of artefacts and at the same time allows the generation of 3D models for 2D objects.

Although work on modelling the appearance of human faces both in 2D and 3D space (Cootes, 2001; Blanz, 1999) and work on augmenting a basic model with additional application depended constraints (Cootes, 1995; Ahlberg, 2003; Blanz, 2003; Xiao, 2004) was described before in the literature, to the best of our knowledge this is one of the first attempts to generate models specific to a certain artistic design style, enabling in that way the reproduction, restoration and authenticity test of artefacts belonging to that style.

In our previous work in the area, statistical face models have been employed for the tasks of 3D face reconstruction from a single 2D view (Lanitis, 2008) and digital restoration of faces in Byzantine icons (Lanitis, 2009). However in those cases a generic face model, rather than a customized model for Byzantine style, was used. As a result shape and chromatic constraints related to Byzantine faces were not properly enforced. We anticipate that with the development of a Byzantine style-specific model the tasks of 3D reconstruction, restoration, reproduction and authenticity verification will be performed with enhanced accuracy.

3. BYZANTINE ART

In this section, a brief history of Byzantine art and associated design rules for Byzantine faces are presented.

3.1 Historical Evolution

Substantially Byzantine art begins around 330 A.D. when the capital of Roman Empire is transported in Byzantium. Byzantine art from the catacombs time has been shaped in a particular form of art with concrete characteristics and special formality. Byzantine art was formed to its characteristic Byzantine image and language identity at the beginning of the 6th century (Popova, 2002). The early period of Byzantine art is followed by the Middle Byzantine period where a flourishing art production peeks during the Macedonian dynasty (867-1055). The Comnenian era (middle of the eleventh century till 1204) leaves a special technotropy style in Byzantine art, the Comnenian (Yuri, 2000). The last dynasty of Byzantium, the Palaeologan, lasting from 1261 to 1453, marks the end of Byzantine Empire. In the Post Byzantine period Byzantine art, is not extinguished but is flourishing in the island of Crete with the famous Cretan school and in many other centres mainly in east Europe.

3.2 Byzantine Art Rules

Byzantine art describes the development of the unique artistic style of the artefacts created in Byzantine Empire. Byzantine iconography, murals, mosaics, or illuminated manuscripts are traditional mediums of Byzantine art practice, depicting holy persons and sacred representations. These representations are continuously produced to the present day, in traditional working methods by icon painters.

While the style of Byzantine art varied considerably during different periods the overall style of Byzantine art remained stable. The various "styles" of Byzantine art are expressed through Byzantine aesthetic ideas determined by the Christian religious consciousness (Popova, 2002). In contrast to the naturalistic religious painting of the West a Byzantine image does not attempt to imitate human physiognomies.

Strictly speaking for faces on Byzantine icons, a "mystical" system of "en face" analogies (Vranos, 2001) reveals the harmonic analogy balance in Byzantine icons. That system describes the use of axes and partitions for human face representation which is based on harmonic analogies between face characteristics like the forehead, hair, eye brows, eyes, the nose, cheek bones, ears, lips, and the chin. Such information is contained in lost writings of the Byzantine period passed from generation to generation along with general instructions on how to make icons and how to represent key icon subjects (Cormack, 2007). Several masters of Byzantine art propose different face analogies for different concrete persons, with slightly different analogy system differences for each individual face representation, for example Jesus Christ, Virgin Mary and other Saints. For each individual case they follow a different analogy system which does not destroys the characteristics of the archetype (Vranos, 2001).

4. GENERATING A STYLE-SPECIFIC MODEL

In this section we present the method used for generating a style-specific appearance model and present our initial quantitative and visual results that aim to assess the applicability of the method to the aforementioned problem.

4.1 Training a Generic 3D Face Model

The first step of the process is concerned with the training of a generic statistical face model for human faces. For this purpose a training set with 60 3D face models of volunteers is used. 3D models used in the training set were captured using a laser 3D scanner and each training sample is represented by the coordinates of the vertices and the RGB colour intensities at each vertex (Lanitis, 2008). A PCA-based model training procedure similar with the one used by Cootes et al (Cootes, 2001) and Blanz and Vetter (Blanz, 1999) is used for building a combined 3D face appearance model. The trained model serves as the basis for a reversible face coding scheme where it is possible to code 3D faces into a small number of model parameters (about 50 in this case) and to generate novel 3D faces by setting values to the 50 model parameters. Provided that the values of the model parameters remain within reasonable limits (approximately 3 standard deviations from the mean values) all generated 3D models represent viable instances of human faces. More details related to the process of training such models appear elsewhere (Cootes, 2001; Blanz, 1999).

4.2 Incorporating Design Rules

In our preliminary investigation we opted to include only few geometrical design rules related to faces appearing in Byzantine icons, in order to test the feasibility of the approach. In the future a comprehensive set of geometric and chromatic rules will be incorporated. In our pilot study the following rules as quoted in (Byzantine Style, 2010) are used:

Rule 1: "The bridge of the nose, the spacing of the nostrils, and the width of the lower lip will have similar measurements"
Rule 2: "The width of the nose should be half the width of the nose at the nostrils"
Rule 3: "The triangle between the pupils and the tip of the nose is almost equilateral"
Rule 4: "The distance between the eyes should be equal to the width of one eye"

Given a 3D face shape it is possible to estimate the deviation of the face from the rules quoted above. During the process 68 preselected vertices among the given 3D face shape are isolated and projected in the 2D space using an orthographic projection. Typical positions of the 68 selected vertices when projected to the 2D space are shown in figure 2. Based on the positions of the landmarks in the 2D space it is possible to estimate all distances required for estimating the deviation from the geometrical rules mentioned above. Figure 2 shows all 11 distances utilized for estimating the compatibility of a shape with the four geometrical rules considered in this experiment. Details about the distances involved in the calculations are listed in table 1.

Distance	Description
d_1	Spacing of the nostrils
d_2	Bridge of the nose
d_3	Width of the lower lip
d_4	Width of the nose at the nostrils
d_5	Width of the nose
d_6	Distance between the eye-centres
d_7	Distance between the left iris and the nose tip
d_8	Distance between the right iris and the nose tip
d_9	Smallest distance between the two eyes
d_{10}	Width of right eye
d_{11}	Width of left eye
$d_{1,2,3}$	The average distance among d_1,d_2,d_3
$d_{6,7,8}$	The average distance among d_6,d_7,d_8
$d_{10,11}$	The average distance among d_{10}, d_{11}

Table 1. The distances used for estimating the deviation of a face shape from the four Byzantine rules considered.

The deviation rules corresponding to each rule are calculated using equations 1-4 respectively.

$$Rule1\_deviation = \frac{\left[\left| d_1 - d_{1,2,3} \right| + \left| d_2 - d_{1,2,3} \right| + \left| d_3 - d_{1,2,3} \right| \right]}{3 * d_6} \quad (1)$$

$$Rule2\_deviation = \frac{\left[\left| d_5 - \frac{d_4}{2} \right| \right]}{d_6} \quad (2)$$

$$Rule3\_deviation = \frac{\left[\left| d_6 - d_{6,7,8} \right| + \left| d_7 - d_{6,7,8} \right| + \left| d_8 - d_{6,7,8} \right| \right]}{3 * d_6} \quad (3)$$

$$Rule4\_deviation = \frac{\left[\left| d_9 - d_{10,11} \right| \right]}{d_6} \quad (4)$$

In order to achieve invariance to scaling each metric is normalized with respect to the the distance between the two eyes (d_6). The deviation metrics for each rule are averaged so that for each given 2D projected shape it is possible to derive a total deviation metric that assesses the overall compatibility of the shape in relation to the four design rules considered. It should be noted that because vertices are projected to 2D as a frontal face, the 3D orientation of a face shape does not affect the distances used for the calculations.

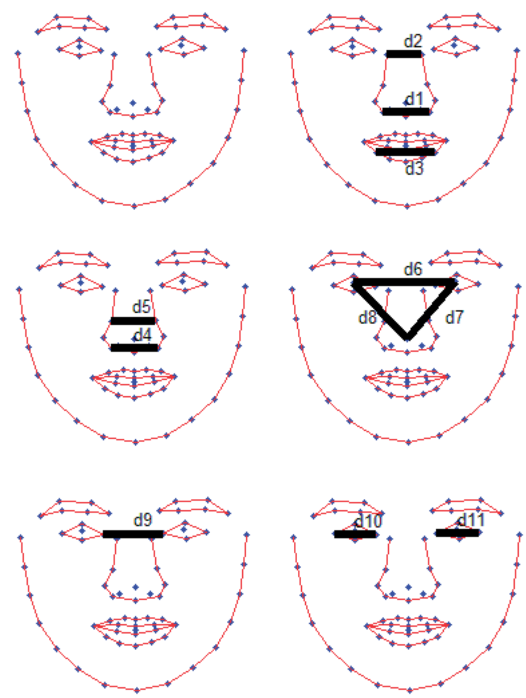

Figure 2: The locations of the 68 landmarks used for incorporating geometric constraints (top left) and the distances d1-d11 used for estimating the deviation of a face shape from the four Byzantine rules considered.

4.3 Training a Style-Specific Model

In order to train a style-specific 3D appearance model a training set is required. Since we aim to train a 3D model for 2D faces appearing in paintings, it is not feasible to obtain a real training set. For this reason we generate a synthetic training set by using a simulation process where a large number of 3D face shape instances (10000 instances in our experiment) are generated by providing to the generic model random values for the 50 model parameters. For each random selection of model parameters, the corresponding 3D face model is generated and the deviation of the shape is calculated based on the rules specified in section 4.2. This enables the separation of the synthetically generated samples into the group of samples that comply with the Byzantine rules considered and the ones that do not comply. Based on the individual training sets identified it is possible to train a 3D model specific to Byzantine faces and a model that mainly represents non-Byzantine faces using the appropriate subset of the randomly generated training set. Figure 3 shows the mean face instance for the model representing Byzantine faces and the non-Byzantine faces respectively. Figure 4 shows random instances generated by each model. When observing the images in figures 3 and 4 it should be taken into account that the method presented only deals with the shape of the face and not the texture hence only differences in the facial shape appear in the images shown. For illustration purposes all face instances shown in figures 3 and 4 are textured using a texture map obtained from a Byzantine icon. By observing the faces in figures 3 and 4 it is evident that both the mean instance and samples generated by the Byzantine style specific model are more compliant to the rules outlined in section 4.2 when compared with faces generated using the non Byzantine model.

Figure 3: The average face generated based on the Byzantine specific model (left) compared with the average face generated based on the non-Byzantine specific model (right)

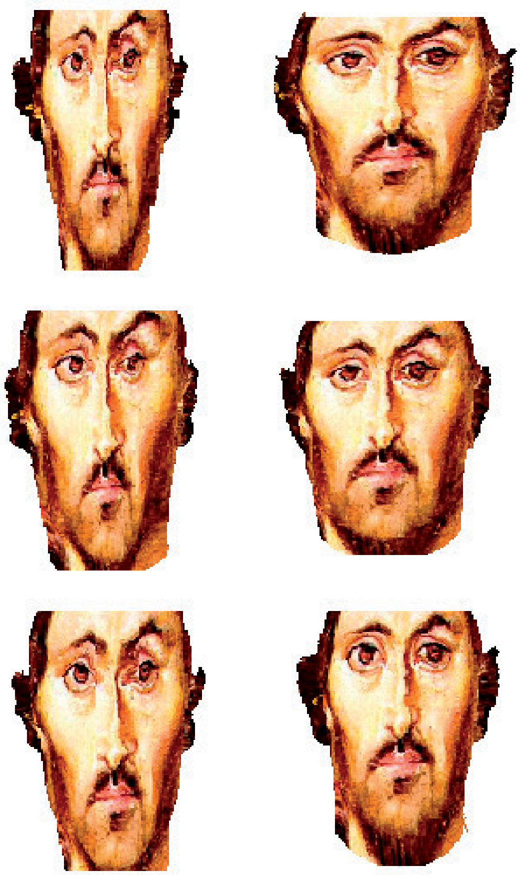

Figure 4: Random faces generated based on the Byzantine specific model (right column) and the non-Byzantine specific model (left column) respectively.

4.4 Experimental Evaluation

The specificity of the customized model to Byzantine faces was evaluated based both on a quantitative test and a visual test.

Quantitative Test: One thousand synthetic 3D face instances are generated using the models representing Byzantine faces and non-Byzantine faces by setting random model parameters to each model. For each generated 3D shape the deviation from the Byzantine rules outlined in section 4.2 is estimated and the resulting histograms are plotted. According to the results (see figure 5) the distribution of the deviation metrics for samples generated by the Byzantine model displays lower values than the distribution of deviation metrics of faces generated by the non-Byzantine model indicating that the Byzantine model has increased specificity to the geometrical constraints enforced. The application of a T-Test significance test indicates that there is evidence at a 99% confidence interval that the two distributions are different proving that the two models generate faces with different geometrical form.

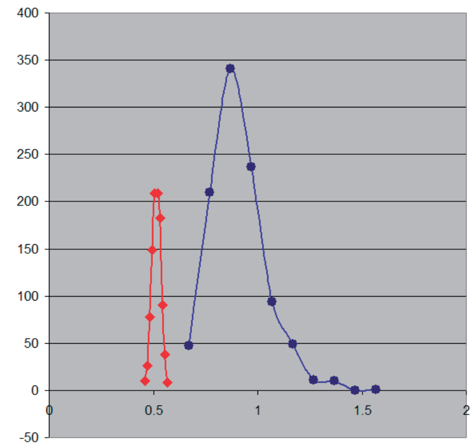

Figure 5: The distributions of the deviation metric for randomly generated faces based on the Byzantine specific model (distribution at the left) and the non Byzantine specific model (distribution at the right) respectively. The vertical axis shows the numbers of samples and the horizontal axis the values of the deviation metric.

Visual Test:

Five random samples are generated using the Byzantine-specific model and five random samples were generated using the non-Byzantine style model. The resulting samples were presented to 15 volunteers who were familiar with Byzantine Icons. Each volunteer was requested to identify the five samples that are more consistent with the Byzantine style. According to the results on average 77% of the samples were classified correctly. This result is promising since in our work we only included four basic geometrical rules for describing Byzantine design rules. It is anticipated that when a more comprehensive set of rules are used, that also include chromatic rules, the human-based classification performance will be increased.

5. DISCUSSION AND FUTURE WORK

A method for building generative statistical 3D face models that incorporate certain design rules is presented. As part of a preliminary investigation of the viability of the method, a Byzantine style specific 3D face model was generated. The performance and effectiveness of the method was evaluated both through a quantitative and a visual evaluation process. According to the results, the resulting model allows the generation of faces that comply with a high degree with a set of design rules incorporated during the training stage. The outcome of the experiments implies that the model has successfully learned the required design rules. Once trained this type of models can be used in a variety of CH related tasks that include 3D reconstruction of faces appearing in 2D artefacts, virtual restoration, digital reproduction and authenticity tests. In all applications mentioned above it is essential to utilize models consistent with the style of the artefacts to be processed, so that appropriate design rules are utilized during the processing stage ensuring in that way that the end results are consistent with the design rules associated with the type of artefacts considered. In our early work on 3D reconstruction (Lanitis, 2008) and virtual restoration of faces appearing in Byzantine icons (Lanitis, 2009), a generic 3D model trained using human faces was utilized as a basis for providing shape constraints that ensure the shape plausibility of reconstructed/restored faces with Byzantine faces. Since the design of faces in Byzantine icons follows certain rules (Vranos, 2001) which are not necessarily compliant to the structure of a human face, it is certain that a use of face model that incorporates Byzantine design rules, like the one described in this paper, will yield more accurate results in the aforementioned applications.

The work presented in this paper presents our preliminary work in this area. We are currently in the process of generating an improved model that incorporates a comprehensive set of geometric and chromatic design rules in relation to Byzantine faces. In this context we plan to use an extended set of geometric rules that refer both to the overall face shape, the distances between certain facial features and the shape of individual facial parts (Vranos, 2001). According to the Byzantine rules, the number and combinations of colors used for painting faces is governed by a set of related rules. We also plan to incorporate colour-based rules in the model so that the resulting model will be able to produce faces whose shape and colours are compliant with Byzantine faces.

Since several variations of Byzantine styles have been used we plan to build both a generic Byzantine model that incorporates the common across styles design rules, and also train individual customized models for different styles adopted by key painters or adopted in certain regions.

In the future we also plan to stage an extended evaluation scheme so that the specificity of a model to certain design rules is assessed through a comprehensive quantitative evaluation and a questionnaire-based evaluation scheme with the help of experts from several related disciplines. Although the method presented has been described in the context of creating a statistical 3D model for Byzantine faces, it is possible to apply the method for other application domains. For example it is possible to build models that incorporate the design style of certain painters who adopted distinctive styles for painting faces so that it will be possible to artificially re-create the style of those painters.

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ANALYSIS, REPLICATION AND COMMERCIALIZATION OF CULTURAL HERITAGE ARTIFACTS BY ADDITIVE MANUFACTURING.

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KEY WORDS: Additive Manufacturing (AM), Rapid Prototyping (RP), Computerized Tomography (CT), digital manufacturing, Stereolithography, Selective Laser Melting (SLM), 3D printing, extrusion, Tiye, Nefertiti, Kahotep, fibula, Celts,

ABSTRACT:

The application of modern methods for non-destructive testing and new digital manufacturing methods like Additive Manufacturing (AM, also known as Rapid Prototyping) are very important tools for the support of research in the field of cultural heritage artifacts. On behalf of the famous busts of the Egyptian queens Nefertiti and Tiye and others, the paper presents the improvement of the research results due to Computerized Tomography, digital reconstruction methods and making 3D physical models using Additive Manufacturing. Having once obtained the 3D data set, AM opens up further possibilities for Marketing and customized production of cultural heritage artifacts. Examples are given and discussed, showing giveaways made from plastics as well as precious one-offs made from metal.

1. INTRODUCTION

All who do research in the field of cultural heritage need to know everything about every detail of an artifact but do neither dare to cut or to disassemble nor or even to touch it. That's why during the hundreds of years before the emerging of non-destructive testing of materials the interior details and consequently many secrets of cultural heritage artifacts remained undiscovered.
In the 1920ies the discovery of the x-rays and the investigation of technical and human material like bone and tissue first made it possible to study the interior structures of interesting pieces without touching it or altering any of its properties. Although it was a tremendous step ahead to an intensive visual investigation it still was just a two dimensional approach. Very often important details were lost, misinterpreted or too much simplified.
In the late 20th century, Computerized Tomography (CT) became available. CT is an X-ray based 3D scanning technology for obtaining images even of the interior sections of an artifact without destructing the original. From this time, fully 3D images and data sets can be obtained from all artifacts, that are made of processable material and that fit the CT scanning device.
In contrast to the imaging technology, the production technologies available were not appropriate to support the investigation and the further use of cultural heritage artifacts. Almost every historic artifact shows what we call "freeform surfaces" and hollow interior structures that barely could be manufactured. In that time, the only way to make replicas or fabricate details for further investigations, for display or for security reasons was to make it manually or based on castings that used manually made masters. The same is valid for the production of commercial copies that very often had been extremely simplified for the same reason.
In the early 1990ies, Additive Manufacturing (AM), that first was called Rapid Prototyping, started to be applied in industry and for medical applications. Using AM, a scaled 3D copy of any artifact that could be described by a 3D data set, was made in a couple of hours without the prior fabrication of tools, molds or dies.
Regarding CT and today's improved surface scanning methods on one side and AM on the other, a powerful set of tools became available for the analysis, replication and thus investigation and commercialization of cultural heritage artifacts. Both are important technologies for the tremendous improvement of the investigation of cultural heritage artifacts.
The paper shows examples of well-known artifacts and widens the focus for extended applications.
The paper does not discuss the supporting technologies like CT, 3D reconstruction and especially AM in detail. To know more about Additive Manufacturing refer to (Gebhardt, 2003).

2. ANALYSIS AND REPLICATION OF CULTURAL HERITAGE ARTIFACTS

The topic is discussed on behalf of a few selected and well-known pieces, the busts of prominent antique Egyptians, and on own studies only.

2.1 The bust of the Queen Tiye

The small bust of Tiye, the principal wife of King Amenophis III and consequently the queen of Egypt (18th dynasty; 1413 – 1377 B.C) wrongly stands in the shadow of the world-famous one of her daughter in law Nefertiti. From the researchers point of view she is even more interesting.
The small (its overall height is just about 10cm) but beautiful bust consists of a wooden scull with carved face framed by a helmet-like bonnet. The bonnet made from some kind of paper machée that covers almost the total scull. In the middle of the forehead two tube-like structures penetrate the bonnet that are assumedly have been linked to the traditional snakes that are missing. The tubes belong to a golden jewelry that is supposed to cover almost the entire head, but mostly is invisibly hidden under the bonnet. A headband covers the upper section of the forehead. Another visible part of the jewelry is a decorated golden stud that is supposed to be linked to the jewelry. Almost three quarters of it can be seen

clearly at her left ear. A similar one is assumed on the right side (Figure1.).

Figure 1: The bust of queen Tiye.
Source: Egyptian Museum Berlin

At any time researchers wanted to know the construction of the entire bust and of all of its elements. As in the 1920ies x-ray became available the bust was taken for investigation. Impressive pictures showed all parts including the wooden base, the bonnet and the jewelry (Figure 2.). Surprisingly the wooden face was covered with another, so far invisible, silver bonnet that seemed to show the original appearance before the paper machée bonnet was applied. This was done to indicate the change of the social status of a queen to the one of a goddess after the death of her husband (Wildung, 1995).

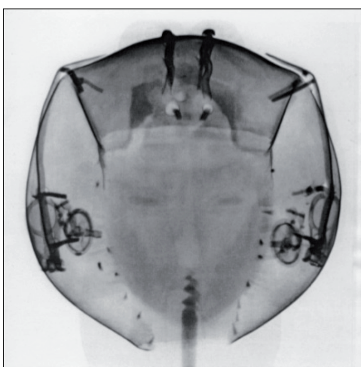

Figure 2: X-ray of the bust of queen Tiye taken in the early 1920ies. Source: Wildung

Although the x-rays delivered a clear impression of the whole arrangement, it remained two-dimensional thus leaving many questions open. Especially the manual replication of its elements, mainly the jewelry, was almost not possible because of the lack of 3D information.
At that time the researchers discussed a possible disassembly of the bust. Therefore a precise and scaled physical 3D copy would be of great interest in order to plan the procedure and to train the people who would do it. But it was not available in that time.
In the late 1990ies a commercial CT scanner, designed for material testing but for medical application, was available at the German Federal Institute for Materials Research and Testing (BAM) in Berlin. After a long-lasting procedure a set of layer data was obtained. A virtual 3D reconstruction was used to obtain a 3D data set of all features. For the first time the whole arrangement could be regarded continuously from any side and all details were clearly visible including its interdependencies (Figure 3.).

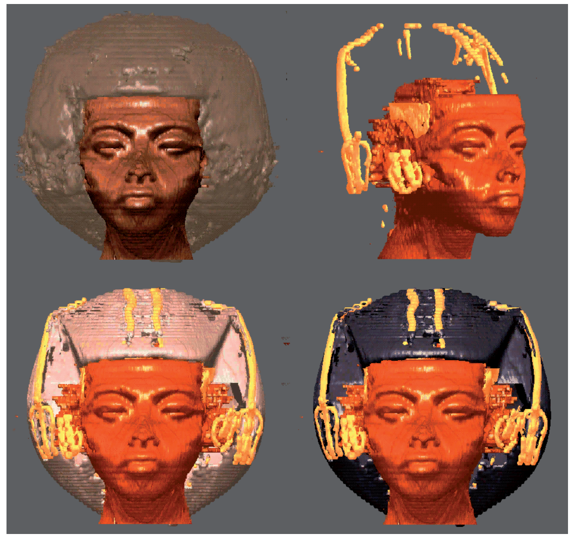

Figure 3: 3D reconstruction from CT scans of the bust of queen Tiye. Source: Illerhaus, BAM

The result proved all assumptions concerning the jewelry and the silver bonnet.
Consequently the idea of disassembling was given up.
But soon didactical reasons caused a new demand for making a copy. The people responsible for the Egyptian Museum in Berlin, first of all the former director Prof. D. Wildung (until the end of 2009), wanted to demonstrate the complexity of the bust to the visitors. Therefore a set of all parts was needed. It was planned to be displayed close to the original. A 2:1 scale was chosen to make details visible and to make sure, that the goal was not a replica but a supporting model.
At this time, Additive Manufacturing (AM) became available, that first was called Rapid Prototyping. AM was capable of making scaled 3D models directly from 3D data sets without the prior manufacturing of molds. As AM works layer by layer, even very complex parts including interior hollow structures, bores and undercuts can be made. As tools are avoided, even one-off's can be made as required in this case.
An epoxy resin based process called Stereolithography was chosen because its ability to process fine details and make a smooth surface. All parts, especially the jewelry but the face and the silver bonnet as well were made using AM and decorated close to the original (Figure 4.).

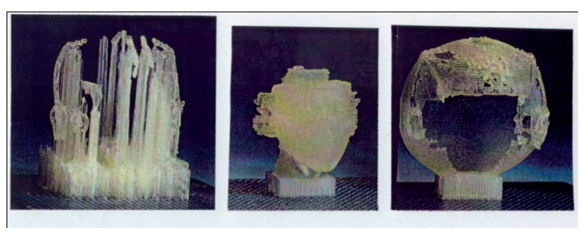

Figure 4: Bust of queen Tiye. Main elements made by AM. Scale: 2:1. Stereolithography. Source: CP-GmbH

2.2 The bust of the Queen Nefertiti

Some cultural heritage artifacts keep interior secrets even if they, in contrast to the above-mentioned Tiye bust, appear as a monolithic statue. A very impressive example is the world-famous statue of Nefertiti (ca. 1370 BC – ca. 1330 BC) made around 1340 B.C. Nefertiti was the Great Royal Wife of the Egyptian Pharaoh Akhenaton.
The bust appears today like it was found 1912 at the workshop of the sculpturer Thutmosis at Amarna who supposedly made it. It is a colored bust made from a monolith and has a height of approximately 50cm (Figure 5.).
As Nefertiti's bust shows a bore at its base, which was used to insert a metal stick for fastening reasons, it was known since its discovery that the bust was made from massive limestone.

Figure 5: Statue of Nefertiti as it appeared in the old Egyptian museum Berlin, Germany. Height approx. 50 cm.

To obtain a smooth surface and to be able to apply the bright colors we can see even now, the limestone was covered with a layer of plaster. It was a guess since many years, but could not be proved, that the application of the plaster was used for some kind of cosmetic improvement too. But as the layer thickness of the plaster could not be investigated without at least partly destroying the original, it was a taboo to touch it.
The use of x-rays did not show reasonable results as the skin-like plaster layer needs to be investigated in all three dimensions in order to obtain a clear picture of the distribution of the layer thickness. Even the first CT scanners did not deliver a sufficient result, because of its comparably big scan layers (2,5mm) and its low power designed to monitor human structures but stones.
The investigation of the bust confirmed, that, while making the bust in the antique, Nefertiti herself served as a model. So, the sculpturer made a real copy of her, including all human imperfections like a clearly visible asymmetry of her shoulders. After sculpturing he used plaster to improve the bust. This result could be clearly verified by the CT scans and the limestone-plaster distribution obtained from virtual 3D reconstruction on the computer. But because of the low resolution due to the big CT layer thickness, and the stair-stepping pattern on the surface caused by this, it remained only a qualitative result.
Knowing about the imperfections of the data as well as of the AM of these days, a first model of the visible bust was made using the AM process of stereolithography. Because the build space of the machine was limited a two-piece bust with a reduced scale of 1:0,7 was made. In 1994 this was the first model worldwide obtained from the data of the original bust (Figure 7.).
In 2006 a new generation of CT scanners was available at the Siemens Imaging Science Institute (ISI) at the Charité hospital in Berlin, Germany. The high resolution obtained from this device and the advanced computer technology that allowed separating even comparably small differences of density that is needed to distinguish plaster from limestone, led to impressively improved results. It led to more detailed information about the plaster-limestone distribution including areas, where the plaster was just absorbed by the surface but did cause no measurable solid layer. The plaster can be seen as yellow areas with the color density as an indicator of the layer thickness (Figure 6.). Many areas show just a powder-like yellow shadow. This indicates that the plaster was just used to improve the surface and to get an even ground for painting.

Figure 6: Digital reconstruction of the bust of Nefertiti. Limestone–plaster distribution according to the improved CT scan in 2006. Source: Siemens

The first idea was to make a 1:1 scale 3D bust showing just the skin-like plaster layer, but it was given up because of the instability caused by the many areas that are covered with no or almost only a neglectable amount of plaster needed to smoothen the surface for painting reasons. According to Figure 6. the plaster distribution can be studied very good just with the scans.
The improved 3D data were very useful to make a high quality 3D-copy. As the AM technology improved as well, a much more accurate 1:1 scale model with better surface quality was obtained (Figure 7. and Figure 8. right).

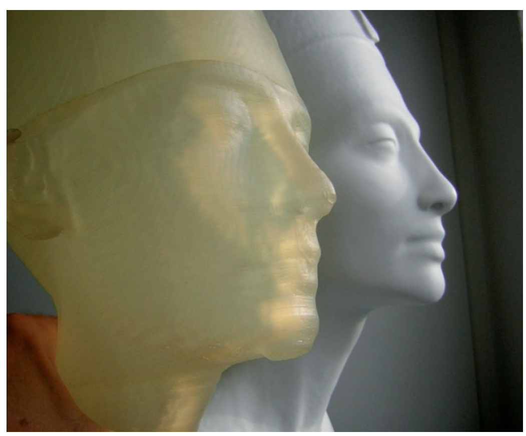

Figure 7: Bust of Nefertiti made by AM (Stereolithography), detail. Model based on the first CT scan (1994, left, unpainted) and on the improved one (2006, right, painted white). Source: Data: Siemens; Models: CP-GmbH
It was made for display. To underline that the goal was not to make a replica, it was painted white.

The model bust was used for various purposes. The most prominent presentation was on Oct. 5^{th}, 2009 two weeks before the official opening of the restored Egyptian museum in Berlin (Oct. 19^{th} 2009). The British Royal Highness, Prince Charles and his spouse Camilla visited the future official presentation site of Nefertiti.
At the spot where the original was going to be placed shortly after, the model was displayed to give the Royal visitors an idea of how it would appear after finishing (Figure 8.).

Figure 8: HRH Prince Charles during the visit of the new Egyptian museum in Berlin prior to the official opening. The model bust was used to indicate the later position of the original. Source: German Television (ZDF 2009)

2.3 The bust of Kahotep

Kahotep was a high ranked official and entitled „privileged friend" at the court of Djed-ka-Re who was the 8^{th} King (Pharaoh) of the 5^{th} Dynasty of the "old empire" and reigned from 2410 to 2380 BC. His grave at Abu-sir was found plundered but a portrait head was left. It is assumed to be a replacement head.
Because of the surface structure at his head that resembles a defective casting it was likely but not certain, that the bust was a cast obtained from the dead-mask.
The bust shows a strange structure at the top of its back section that could be caused by damage. This was likely because the nose as well was damaged. But in contrast to other damages the back section of the head was somehow symmetric.

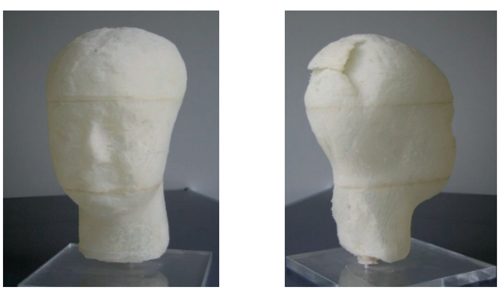

Figure 9: Model of the bust of Kahotep. Front-and back view. Stereolithography. Source: CP-GmbH

An investigation as described before, using CT, digital reconstruction and AM, was done and led to a Stereolithography model of the head including the structure of its back. It makes visible a roll-shaped section that is assumed to consist of some fabric with the hair enrolled (Figure 9.). This often is done prior to the application of some release grease while preparing to take a mask.
The bust of Kahotep is not further investigated until now, but the initial supporting work is done.

3. REPLICATION AND COMMERCIALIZATION OF CULTURAL HERITAGE ARTIFACTS

The examples above already show some replicas or models of original artifacts or details of it. All of them were, at least initially, made to support the professional researcher's work.
Doing so, additional applications are arising, such as the support of the exhibition pedagogic, public relations and advertising or display alternatives to conserve the original.

3.1 Models and Replicas for public relations

While public budgets are shrinking even of well-known museums, their representatives have to think about new ways of generating income. A suitable approach is to take the most prominent pieces of a museum and treat them as "stars". Although this is a proven concept since many years, AM opens up the chance, to improve it.
As AM, for example, is suitable to generate arbitrary scaled models from different materials, even world famous pieces appear in a new and exceptional light.
Advertising with scientific elements mostly underlines the real or assumed secrets linked to cultural heritage artifacts. This generates attention not only from the potential visitors but from the media as well that act as a propagator – in most cases even for free.
As an example, the installation of the 1:1 scaled bust of Nefertiti at the pre-opening event at the new Egyptian Museum Berlin was mentioned above (Fig. 8.). It was perfect to illustrate, where the original will be placed soon after. The white color underlined the character of a substitute. Nevertheless it was another kind of original – valuable enough to meet the events level.

3.2 Replicas and Models for sale

It is important to keep in mind, that AM replicas and models are not a result of the interpretation by an artist as today's traditionally manufactured replicas mostly are. The 3D data set is obtained directly from the original. That is why the models are authentic.
For the museum it is a great advantage that the data are obtained from the original. The data set is exclusive because it is under copyright protection. More important, the data can only be obtained with the museums prior allowance and support. The model busts of Nefertiti shown above can be taken as examples.

3.2.1 Different processes and Materials: But AM opens up new marketing and sales strategies. As today's AM covers five different process families (Gebhardt, 2003) that are capable to process different materials like plastics, metals or ceramics on one hand and to make solid, hollow, translucent, colored or monochromatic models, there is a great choice on different modeling methods.
AM processes, like Stratasys's plastic extrusion (Dimension), can be used to make even giveaways (Figure 10.). Its height is about 5cm. The busts can be made from various colors. The series of models cover the whole build space. On the picture the busts are still on the build platform showing the supports that need to be removed to obtain the finished model.

Figure 10: Miniature bust of Nefertiti. (Dimension, Stratasys). Source: RP-Lab, Aachen University of Applied Sciences

At the upper end of the price range, metal AM processes allow the making of jewelry-like pieces of art. Figure11. shows a bust of Nefertiti made from Medical Implant (CoCr)-steel. It can be made from Titanium or Gold as well.

Figure 11: Miniature bust of Nefertiti, Metal. Source: RP-Lab, Aachen University of Applied Sciences

The bust has a height of approx. 3cm. It is made by Selective Laser Melting (SLM). Figure 11 shows the model as it comes out of the process (left), after removal of the supports (center) and after manual polishing (right)
The scaling of the models mentioned above covers the range from 1.1 down to 1:25. Basically it is not limited but the wall thickness might need adjustment.

3.2.2 One-of-a-kind customized Replicas: For many people interested in antique pieces it is very desirable to get a personal copy of an original, even if it is scaled or personalized in another way. A very personal version is to make miniatures from precious metals.
Sure, a traditional jewelry maker could do this as a "one-off". But AM offers an alternative in terms of price and production speed. Additionally, and this may be the most important argument for clients interested in cultural heritage artifacts, using the 3D data obtained from the original proves that no artistic interpretation is added to the piece.
So-called fibulas, forefathers of today's fixing pins for clothing can be taken as examples. They were already used in the Celtic period that roughly ranged from around 750 B.C until 50 B.C. The Celts spread over almost today's West- and Central Europe. They left a huge amount of cultural goods including fibulas in many places.
The prominent excavation site and research center called Dürrnberg at Hallein, Austria, covers thousands of fibulas already on display in the museum. But at least the same amount waits in the ground. As they will be scanned for documentation in any case, this opens up the possibility to use the scan to make one-of-a-kind pieces or a small series according to the orders of individual customers.
Figure12. shows a 1:1 scale replica of a fibula (Height ca. 2cm) found at the Dürrnberg site. It is made using a laser-based metal AM process called Selective Laser Melting (Gebhardt, 2005; Gebhardt et.al., 2010). The partly finished model, still with supports that are needed for the build (left) and the finished piece (yet without fastener needle, right) are displayed.

Figure 12: Fibula, Celtic. Selective Laser Melting (SLM). Source: RP-Lab, Aachen University of Applied Sciences, Celtic Museum, Hallein, Austria

4. CONCLUSION

Modern non-destructive testing methods, originally developed for medical imaging or to support industrial product development and quality management (QM) procedures, are valuable tools for the investigation and replication of cultural heritage artifacts.
CT scanning and other digital imaging processes (like ultrasonic (US)) along with simulation programs provide good bases for the visual investigation of the interior of even arbitrary complex parts.
Based on these data sets, Additive Manufacturing allows the making of replicas from different materials such as plastic, ceramic or even precious metals. It can be scaled to make details visible. It can be used not only for research but for marketing purposes as well.
In future, comparably cheap AM processes, so called Fabbers, will make cheap models and advanced AM processes will allow to make multi material pieces showing hard and soft areas for example. Functions will be integrated and bring technical achievements of the past to new life.
Future AM processes will be able to make replicas that can barely be distinguished from the originals. This will reduce the need to transport them for display and open up new security strategies.
New customer relations like internet-based museum visits will bridge the distance between the interested people and the museum site. Internet -based shopping will be directly linked to virtual museum visits and selected parts can be ordered as "one-offs".

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The work described, actually is carried out using new and emerging AM technologies and materials. But the sources go back to the very beginning of AM in the late 1980ies. Therefore many people were involved over the years and many of them still are. As one of the initiators Prof. Dietrich Wildung, the Director of the Egyptian Museum, Berlin (until 2009) was deeply involved. Further I thank my colleagues from the CP-GmbH, Erkelenz, Germany, who supported with the build of most of the models and my colleagues from the

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Digital Libraries and e-Preservation in Cultural Heritage

Part I

PROTECTION OF CULTURAL PROPERTY FROM LOOTING AND THEFT: UPDATING OBJECT ID

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KEY WORDS: Object ID, documentation standards, Metadata, protection of cultural property, looting and theft, art trafficking, movable cultural property, art theft databases

ABSTRACT:

According to Interpol, FBI, and other international and national law enforcement agencies, illicit trafficking in art is a multibillion dollar industry worldwide and the third largest grossing criminal industry behind only drugs and arms! Believed to be closely connected with money laundering, it is a funding source for terrorism and in many cases leads to the devastation and destruction of cultural heritage. Interpol's head of trafficking in cultural property points out that there is little chance of recovering a stolen object, if there is no descriptive record or photograph. This would include works stolen from a private home, museum, or works looted during times of war. In response to the difficulty of tracking and recovering stolen cultural property, UNESCO, International Council of Museums (ICOM), United States Information Agency (USIA), and the Council of Europe under the leadership of the Getty Information Institute launched Object ID in 1997 at an international conference in Amsterdam. The need for the data standard was recognized by the director of the former Getty Information Institute, Eleanor E. Fink who developed the strategic plan and led the alliance that eventually produced Object ID. Prior to Object ID, reporting a stolen work of art and trying to recover looted or stolen property was far more cumbersome and chaotic than it should have been at the brink of an information age. It has been over ten years since Object ID has been evaluated and updated. Finally a new effort is underway to convene regional symposia on Object ID and evaluate its usefulness. The effort will also award grants and organize training events to help cultural heritage communities and centers as well as museums in developing countries apply Object ID. By collaborating with law enforcement, it will also provide training to police and customs officials on how to make use of Object ID for recovering looted or stolen cultural property.

1. INTRODUCTION

Looting and theft of art and antiquities has increased significantly over recent years. This past year alone, some remarkable art thefts have occurred such as the loss of five cubist and post impressionist paintings from the Museum of Modern Art in Paris. This year thieves also stole ca. 30 paintings, including works by Pablo Picasso and Henri Rousseau from a house in the Provencal village of La Cadiere d'Azur. In the past two decades, art heists have occurred almost yearly: 1991, 1993, 2003, 2004, 2007, and 2008 (Washington Post, 2010. See APPENDIX A for a listing of major art thefts). One of the largest art thefts in world history occurred in Boston, Massachusetts in 1990 when thieves stole 13 pieces, collectively worth $300 million, from the Isabella Stewart Gardner Museum. A reward of $5.000.000 is still being offered for information leading to their return.

It is generally believed that criminals find it much easier to transport cultural property across international borders than money or drugs. Paintings when removed from their frames can easily fit into a suitcase. The item can be camouflaged or disguised by placing it in another frame to appear more commercial. Coins, jeweled boxes, drawings, vases, small statues, etc. can be passed as souvenirs.

The thief may try to claim a reward for the theft or offer the item on the black market for a fraction of its value. According to the head of Scotland Yard's Art and Antiques Unit, there is indisputable evidence that criminal networks are involved in art crime and that the money made goes into the coffers of drug and arms dealers, even terrorists (Time, 2008).

While exact figures for illicit trade of cultural property (including stolen art, fakes, forgeries and looted artifacts) are unknown, law enforcement agencies estimate it is around $6 billion a year (Time, 2008).

2. REPORTING STOLEN CULTURAL PROPERTY

Fortunately, most museums in the developing world have documents describing their objects, and in many cases there may also be a photograph. When items are stolen from a museum, the report can be entered into an art theft database. Interpol is one of the key international law enforcement agencies that maintains such a database on stolen cultural property. Law enforcement agencies in other countries also may maintain their own databases. For example, in Italy the Carabinieri have developed an extensive database as has France. The Art Loss Register, funded by insurance companies and auction houses has one of the largest private databases on art theft.

While entering a stolen work of art in an art theft database does not guarantee its return, it is the best means of broadcasting internationally that it is missing. However, as Interpol has emphasized, without a written document and photograph it is almost impossible to locate a stolen work.

Sadly, thousands of items are looted around the world for which there is no documentation. The most vulnerable targets for looting and theft are items taken illegally from archaeological sites as well as developing countries. (e.g., looting of art from the Middle East, Asia, Africa, and Latin America). How would the case of the Kanakaria mosaics that were stolen from a Greek Orthodox Church in the Turkish-occupied area of Cyprus and turned up for sale in the United States by an art dealer in Indiana have been handled without photographs and published documentation? Photographs depicting the mosaics in situ that were taken before the Turkish invasion were admitted as evidence at the court trial as part of the proof of the church's ownership.

The challenge of efficiently reporting and locating stolen cultural property was particularly acute in the early 1990s. The situation was due to several factors:

- Lack of compatibility or common standards across law enforcement databases.
- Inability (due to lack of standards) to search across various art theft databases.
- Lack of a core standard for reporting and uniquely identifying cultural property that was simple enough for a non-art specialist such as a customs official or law enforcement officer to use.
- Lack of close cooperation across agencies involved in setting policy frameworks and/or standards for protection of cultural property (e.g. ICOM, UNESCO, Council of Europe, European Commission, US Information Agency, Conference for Security and Cooperation in Europe).
- Lack of simple and inexpensive tools for developing countries to document their collections or cultural property. This was also true for Eastern European countries that had come out of the Cold War and were being plundered by thieves.

3. NEED FOR OBJECT ID

In 1992, Eleanor Fink, at the time a program officer at the Getty Information Institute was visiting Interpol Offices in Washington when a report came in about some works of art that were taken from a museum in the Netherlands. The next steps were laboriously slow. It would take several weeks to share the theft information with other police agencies once the documents describing the works stolen sent by the police in the Netherlands were translated!! How ironic at the dawn of the information age that a thief could move a stolen object across a border faster than the information itself could be distributed to the relevant agencies that could help recover it! Further investigation indicated that there was no compatibility across art theft databases and little cooperation among key agencies that would address this problem. It was a challenge that was ripe for the Getty Information Institute.

The former Getty Information Institute (abolished during a corporate reorganization of the Getty in 1999), was widely recognized as an international leader in helping organizations use or adopt information technology and for producing some of the key metadata standards and vocabularies needed to protect, manage, and network art and humanities information (e.g. Art & Architecture Thesaurus, Categories for the Description of Works of Art, Union List of Artist Names, Thesaurus of Geographic Names, Introduction to Imaging)*.

Fink began to conduct interviews with heads of umbrella organizations involved in protecting cultural property to discuss the need for a core data standard, both simple and effective, to uniquely identify cultural objects. These agencies included ICOM, UNESCO, Council of Europe, European Commission, Interpol, US Information Agency, and the Conference for Security and Cooperation in Europe.

Initially, the challenge was to convince the agencies to work together. When Fink became the Director of the Getty Information Institute, she organized and convened a meeting in Paris in 1993 that brought the organizations together. A white paper was delivered calling for action and cooperation. The paper pointed to data on looting and art theft and indicated that the magnitude was too large for any one agency to stem and/or solve. It proposed a collaborative effort to identify a core data standard by conducting surveys. All agreed to collaborate, help conduct surveys, identify a core information standard, and help implement the standard. The result was the formation of an alliance to develop what later became Object ID (Fink, 1993).

4. CONSENSUS BUILDING METHODOLOGY

Convincing organizations to work together and agree on common information standards can easily fail if not approached carefully. Most organizations are committed to the standards and systems they have developed. The approach utilized for reaching agreement on data categories for Object ID was one well practiced by the Getty Information Institute (Fink, 1999):

- **Survey Documentation Practices**. In the case of Object ID, the agencies in the alliance contributed membership lists and the Getty Information Institute hired consultants to prepare and send out surveys to member organizations in 42 countries (Thornes, 1997).
- **Form an Alliance**. The surveys were distributed under the logos of the alliance (e.g. ICOM, UNESCO, and Council of Europe).
- **Analyze and Point to Common Practices.** The data from the surveys was analyzed to indicate where there was agreement and a report was prepared. From this step, a core data standard emerged.
- **Convene Specialists**. Meetings were convened with conservators and other experts to determine what inscriptions and markings and distinguishing features should be included. For example, cast markings, visible damage, etc. that could uniquely distinguish one object from another.
- **Host Open Discussions**. Focus groups were convened over the next two years across agencies involved in art and culture to discuss the findings and the proposed Object ID format
- **Demonstrate Common Values and Build Consensus**. Object ID was presented not as a replacement for stakeholders' systems but rather as a core data standard that was already nestled in any given system. Thus, while information for each cultural heritage organization varies from checklist data to scholarly research, all need documentation that will identify objects.

Gradually consensus was built for Object ID across many disciplines: art trade, insurance companies, law enforcement, museums, heritage centers, national inventories, archaeological organizations, and appraisers.

5. OBJECT ID CHECKLIST

Over 170 organizations in 42 countries responded to the survey. The majority of the responses came from museums and galleries (75) followed by documentation centers (16) law-enforcement agencies (7) and other (Thornes, 1997).

* The Getty Information Institute and the Getty Education Institute were abolished in 1998/99 during a corporate reorganization of the J. Paul Getty Trust. By 2001 the directors of all remaining Getty Institutes and the museum had been replaced.

Consensus for what information is needed to uniquely identify an object as well as consultations with conservators on detecting distinguishing features formed the Object ID checklist:

5.1 Type of Object

What kind of object is it (e.g., painting, sculpture, clock, mask)?

5.2 Materials & Techniques

What materials is the object made of (e.g., brass, wood, oil on canvas)?
How was it made (e.g., carved, cast, etched)?

5.3 Measurements

What is the size and/or weight of the object? Specify which unit of measurement is being used (e.g., cm., in.) and to which dimension the measurement refers (e.g., height, width, depth).

5.4 Inscriptions & Markings

Are there any identifying markings, numbers, or inscriptions on the object (e.g., a signature, dedication, title, maker's marks, purity marks, property marks)?

5.5 Distinguishing Features

Does the object have any physical characteristics that could help to identify it (e.g., damage, repairs, or manufacturing defects)?

5.6 Title

Does the object have a title by which it is known and might be identified (e.g., *The Scream*)?

5.7 Subject

What is pictured or represented (e.g., landscape, battle, woman holding child)?

5.8 Date or Period

When was the object made (e.g., 1893, early 17th century, Late Bronze Age)?

5.9 Maker

Do you know who made the object? This may be the name of a known individual (e.g., Thomas Tompion), a company (e.g., Tiffany), or a cultural group (e.g., Hopi).

5.10 Write A Short Description

This can also include any additional information which helps to identify the object (e.g., color and shape of the object, where it was made).

5.11 Take Photographs

Photographs are of vital importance in identifying and recovering stolen objects. In addition to overall views, take close-ups of inscriptions, markings, and any damage or repairs. If possible, include a scale or object of known size in the image.

5.12 Keep it Secure

Having documented the object, keep this information in a secure place.

6. WHAT OBJECT ID ACHIEVED

Once launched in 1997, the standard was widely embraced by the international cultural heritage community.
The tenth meeting of UNESCO's Intergovernmental Committee for Promoting the Return of Cultural Property (Paris 25-28 January 1999) endorsed Object ID "as the international standard for recording minimal data on movable cultural property" and recommend that all "UNESCO Member States adopt 'Object-ID' and use it, to the fullest extent possible, for identification of stolen or illegally exported cultural property and international exchange of information on such property" (Resolution 5).
Interpol, the Carabinieri, and other national law enforcement agencies now use the Object ID checklist as the basis for their art theft databases. It is also the basis for the Art Loss Register's art theft database and for the form used to report stolen cultural property (see APPENDIX B for a list of organizations using Object ID).
ICOM conducts training in Object ID and sees its value in helping museums in developing countries document their collections and establish an inventory. Insurance agencies have been using Object ID as a means for their clientele to document their personal cultural property.
The US Military prepared a training manual (GTA-41-01-002) entitled Civil Affairs Arts, Monuments and Archives Guide that prepares its civil affairs forces to recognize and document cultural property. The Object ID checklist is the basis (pages 29-31).
Through the Tropenmuseum in Amsterdam, Object ID was implemented in 14 former Dutch colonies throughout the developing world and translated into 14 languages (see APPENDIX C for a list of countries that use Object ID).
Thus what contributed to the chaos in reporting and tracking stolen cultural property prior to 1997, was addressed after the launch of Object ID:

- Compatibility across major art theft databases.
- A core standard now used for reporting and tracking stolen cultural property.
- Endorsement of Object ID by key umbrella organizations.
- UNESCO policy proposing member states adopt Object ID.
- Outreach to developing countries to provide training in Object ID that serves as a means of documenting collections and establishing an inventory.

Today, more than ever, a standard like Object ID is needed. In the mid-1990s art theft particularly looting of art in the Eastern block countries was a dominant problem. In this decade, art taken from Asia and Latin America and restitution of art has become a huge issue (return of Greek and Italian antiquities, looting of treasures from Iraq, art looted during World War II, art taken by the Nazis etc.). In all these cases, it is almost impossible to determine if a work has been stolen unless there is good documentation.

7. THE STATUS OF OBJECT ID

While Object ID has become an international standard for describing art, antiques and antiquities that establishes the minimum level of information needed to uniquely identify an object, it has not been examined, updated, or expanded since its launch in 1997!

Unfortunately, there are currently no agencies fully responsible for the upkeep of Object ID that would include convening stakeholders to update its effectiveness: to explore if information should be added and if advances in technology could improve Object ID. The J. Paul Getty Trust that funded its creation has stated that it does not have the resources to maintain Object ID. ICOM and Interpol conduct workshops in the use of Object ID, but do not have sufficient funding. Ironically, after a multi-year investment to establish a cooperative alliance of agencies that helped to produce Object ID; UNESCO's resolution that member states use Object ID; and its implementation across law enforcement databases, the standard is being neglected with respect to maintenance and upkeep. Unlike 1997 when Object ID was launched, there has been tremendous progress in Information Communications Technology (ICT). Open Source Software, as one example, has made it easier to replicate and coordinate applications across specific databases.

Searching by image once thought too expensive has now become feasible. Image recognition searching for a stolen work of art would be particularly valuable in cases where the auction house or law enforcement does not have core identifying information (e.g. name of artist, media, place of origin, etc.). Today it would be possible to take an image and run it against Interpol's or the Carabinieri's art theft databases and potentially find a hit. While there are often problems searching for images that have been taken from different angles, 3-D image searching compensates for this variable. For example, Microsoft's image recognition software is capable of extracting a high degree of accurate matches despite image variables.

Cloud computing infrastructure provides advantages in dealing with large data sets, the ability to adapt and scale rapidly with regard to technical need and vast storage.

There have also been advancements in tagging objects that previously were considered harmful to the integrity of the object.

Museums and cultural heritage centers in developing countries need more help in documenting their holdings than ICOM can provide, and Interpol cannot provide sufficient training to customs and law enforcement officials as they would like.

8. CONCLUSION

8.1 Funds for the Protection and Recovery of Cultural Property

Object ID has been widely endorsed and is the basis for all major art theft databases. But there is currently no organization responsible for its upkeep. Both ICOM and Interpol see demand for scaling up the training in Object ID they currently provide. However, neither organization has sufficient funding to handle and manage this alone.

Therefore a private fund is being established by the author of this paper. An international advisory committee will help guide the Fund which will make grants to individual projects in developing countries that need help implementing Object ID. In addition, the Fund will cover costs to convene symposia on regional levels to explore Object ID's usefulness and update the standard if needed. It will explore how new technologies can work in conjunction with Object ID to better track and recover stolen cultural property. It will also provide grants to organizations like ICOM that provide training in Object ID. An independent evaluation will be conducted on the training and grants awarded after the first two years to assess effectiveness and longer term need.

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APPENDIX A. EXAMPLES OF FAMOUS ART THEFTS

- *Last Judgment* triptych by Memling (1473)
- Gainsborough's *The Duchess of Devonshire* (1876)
- The *Mona Lisa* (1911)
- Panels from the *Ghent Altarpiece* (1934)
- Quedlinburg medieval artifacts (1945)
- Alfred Stieglitz Gallery (1946)

- University of Michigan (1967)
- Izmir Archaeology Museum (1969)
- Stephen Hahn Art Gallery (1969)
- Montreal Museum of Fine Arts (1972)
- Looting of Cypriot Orthodox Churches following the Turkish Invasion of Cyprus (1974)
- Picasso works in the Palais des Papes (1976)
- The Gardner Museum (1990)
- Mather Brown's *Thomas Jefferson* (1994)
- Cooperman Art Theft hoax (1999)
- The National Museum of Fine Art (*Nationalmuseum*), Stockholm, Sweden (2000–2005)
- Stephane Breitwieser - The "Art Collector" (c. 2001)
- Russborough House (1974, 1986, 2001, 2002)
- Frankfurt art theft and "Operation Cobalt" (1994-2003)
- Edvard Munch works (1994, 2004, and 2005)
- Saliera (2003)
- Jacob de Gheyn III
- Museu da Chácara do Céu (2006)
- Hermitage thefts (2006)
- São Paulo Museum of Art (2007)
- Pinacoteca do Estado Museum (2008)
- Musée d'Art Moderne de la Ville de Paris (2010)

APPENDIX B. ORGANIZATIONS CURRENTLY USING OBJECT ID

- Appraisers Association of America
- Art Loss Register (London and New York)
- Chubb and Son, Inc.
- Council for the Prevention of Art Theft (UK)
- Documentation Committee, International Council of Museums (CIDOC)
- Dutch Inspectorate of Cultural Heritage
- Royal Tropical Institute licensed software and provided training in how to use their Object ID software
- Federal Bureau of Investigation
- Gallery Systems
- Heritage Council (Ireland)
- Incorporated Society of Valuers and Auctioneers (UK)
- International Council of Museums (Africom standard)
- Interpol-France
- Interpol-USA
- Museum Documentation Association (UK)
- Nordstern Versicherung (Germany)
- Scotland Yard (UK)
- UNESCO
- US Army

APPENDIX C. DEVELOPING COUNTRIES INTRODUCED TO OBJECT ID

- Benin
- Bolivia
- Burkina Faso
- Cambodia
- Chile
- Egypt
- Ethiopia
- Ghana
- India
- Mali
- Mozambique
- Palestinian Authority
- Sri Lanka
- Tanzania
- Vietnam
- Zambia

THE DIGITAL FACTS OF CULTURAL HERITAGE

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KEY WORDS: Digital Heritage Statistics, Numeric, Sig-Stats, Enumerate, Netherlands, Monitoring, The Digital Facts

ABSTRACT:

This short paper presents some results of research into the current practices of digitisation by cultural heritage institutions across Europe. The paper addresses activities that were set up in the context of the EU-funded project Numeric (2007-2009), such as the Special Interest Group on Cultural Heritage Digitisation Statistics. The paper will focus in particular on monitoring activities conducted in the Netherlands. The Netherlands were able to provide reliable data from 131 heritage institutions to Numeric, which turned out to be the largest contribution of all participating countries. These monitoring activities went beyond the scope of Numeric and also included topics such as born digital heritage that were not addressed in Numeric. Finally, a possible follow up to Numeric will be discussed.

1. INTRODUCTION

In recent years, there has been an increase in the need for intelligence about the progress of digitisation of cultural heritage. Since the early nineties, most cultural heritage institutions have engaged themselves in digitisation projects, ranging from mass digitisation projects of newspapers and audio-visual materials to small scale activities, for example to promote the highlights in a specific collection. Many of these projects were financed with public money, often through additional funding from local or national governments, public funds or the European Commission. What can we say about the total amount of cultural heritage that has been made available digitally, online or on site? How much has been invested so far? And is there any reliable data to be given about the use of the digital collections? If we are able to provide answers to questions like these, we will be able to better plan and manage our future digitisation activities.

Monitoring digitisation activities has been done for quite some time now. In Europe, many European FP7, eContentPlus or ICT-PSP projects start with a survey to determine the current status or size of digital collections, the use of metadata schemes and other standards, or the availability of databases and other services. The Lund meeting from 2001 in particular led to a better common approach to quality assurance for the use of ICT by cultural heritage institutions. In various EU-countries surveys were set up to understand better the trends and needs of the institutions and their users. International initiatives like EGMUS (European Group on Museum Statistics) included data on ICT and digitisation as well. However, an overall methodology for monitoring the progress of digitisation of cultural heritage was lacking. It was considered useful for both policy makers and institutions to set up a large scale survey that would define the empirical measures for digitisation activities and establish the current investment in digitisation and the progress being made by Europe's cultural institutions. This became the Numeric project.

2. NUMERIC

Between 2007 and 2009, the European Commission contracted UK-based CIPFA (formerly The Institute for Public Finance) to undertake the Numeric study to

1. test a framework for collecting and analysing data relating to digitisation activities of materials held by libraries, archives and museums in the EU and
2. implement this with the help of nominated experts in each European Country.

Numeric was a groundbreaking effort to collect and harmonise statistical data on digitised cultural heritage across all EU-member states. The key instrument was a rather extensive questionnaire, which addressed topics like information policies, size of collections, investments, staff involvement, use of standards and usage of digital collections. To support this survey tool, Numeric developed other instruments, such as a terminology list and a tool to determine a representative sample of cultural heritage institutions in each country.

The two most important results of the Numeric project were the Study Report (published as a draft in May 2009, the final version was published in February 2010), and the Numeric Framework, a group of institutions and persons, brought together through a shared interest in the Numeric objectives. In each EU-country, a National Coordinator was appointed, usually by the Ministry of Culture. These National Coordinators were instrumental in promoting the Numeric Survey across Europe and involving heritage institutions to contribute their data.

In total, 788 respondents from 26 countries participated in the Numeric Survey. In itself quite a respectable number, which provides a proper foundation to the facts and figures presented in the Study Report. Here are two interesting outcomes of the Numeric Study:

Table 15 Progress made towards the digitisation of collections

Type of institution:	Part of collection digitised % [1]	'Order book' Completed % [2]	'Order book' Outstanding % [3]	Equivalent backlog [3]/[2] [4]
Archives	5.1	10.3	89.7	8.7
A-V or film institutes	9.8	15.4	84.6	5.5
Broadcasting institutes	10.8	12.8	87.2	6.8
Art/archæo museums	27.2	30.6	69.4	2.3
Science and tech museums	25.5	32.4	67.6	2.1
Other museums	17.5	23.1	76.9	3.3
National libraries	2.3	3.5	96.5	27.6
Higher education libraries	2.5	4.4	95.6	21.9
Public libraries	14.8	31.9	68.1	2.1
Special or other libraries	5.5	12.2	87.8	7.2
Other types of organisation	22.5	29.0	71.0	2.4

Figure 1: Table 15 from the Numeric Final Report

Table 15 provides an overview of the average part of the collection that has been digitised so far. The 'Order book' refers to the part of the collection that an institution intends to digitise. With the equivalent backlog, it can be calculated how much more cultural heritage needs to be digitised. For example: The amount of archival collections to be digitised equals the current size multiplied with a factor of 8.7.

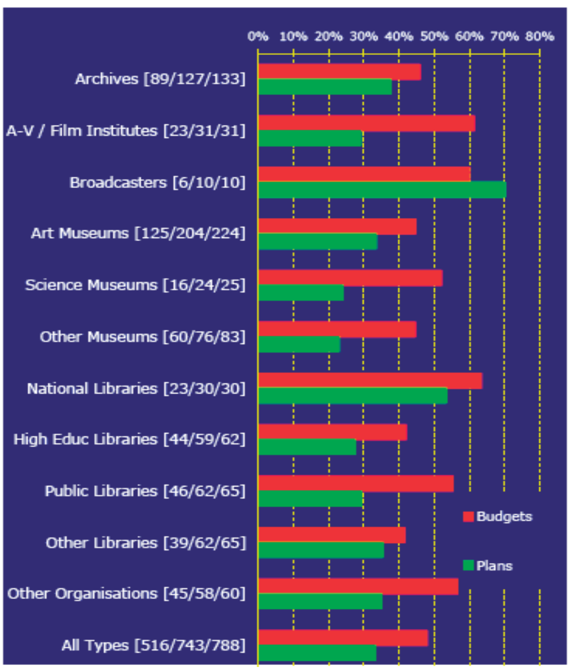

Figure 2: Figure 5 from the Numeric Final Report: "The first two figures in brackets indicate the number of institutions respectively responding to the question about their (1) BUDGET and their possession of a (2) PLAN; the third figure is the total number of (3) survey responders. Some will not have indicated that they possess a budget or a plan; the proportion that did is indicated by the bars in the chart."

This second graph shows how many institutions have a policy plan on digitisation in relation to the amount of institutions that have a specified budget for digitisation. With the exception of broadcasters, all cultural heritage domains have (considerably) more specified budget than they have policy plans. In short: there is a lot of 'ad hoc' digitisation going on.

Relevant and interesting as these results may be, it has to be said that the responses from across the EU to Numeric were rather unbalanced. With 131 contributing institutions, the Netherlands provided the largest set of data, while countries with much larger cultural heritage communities provided far less data (from Italy and France, only 30 institutions participated in Numeric). From the beginning, Numeric identified commitment from heritage institutions as a key factor to success. During the project, two workshops were organised for the National Coordinators, to discuss the methodology, approach, and the preliminary results and future options. One of the recommendations to emerge from these workshops was to set up a Special Interest Group, dedicated to developing the standards and definitions for future survey activities.

3. SIG-STATS: recommendations for a follow up

The National Coordinators from six EU-countries volunteered to set up this Special Interest Group, called SIG-STATS: Austria, Belgium, France, Germany, Hungary and the Netherlands. The installation of SIG-STATS was endorsed at the meeting of the Member States Expert Group, on 1 October 2009. In February 2010 the SIG met in Luxembourg to prepare the recommendations for a follow-up to the Numeric study. The SIG addressed seven topics that needed closer attention:

1. Survey design: principles to structure the questionnaire(s)
2. Defining the survey sample: the criteria for identifying 'relevant' institutions
3. Definitions: improving the 'vocabulary' of the questionnaire and harmonising it in the EU27 languages
4. Input-output measures: how to link the analogue heritage to the digital representations
5. Calculation of costs
6. Measuring usage and access: valid and practical means of measuring access to and use of digitised heritage
7. The framework: organisation and implementation of the survey across the EU27 countries

For each of these topics, the SIG discussed possible improvements. A key principle for the SIG was that the follow-up should not only be about the gathering of data about the here and now; it should also support the heritage institutions to get more 'in control' of their digitisation activities, by showing them the usefulness of having better intelligence about the size, costs and usage of their digital collections. The follow-up to Numeric should not be only about short term statistics, but also about long term accountability and performance indicators. The consequence of this principle was that it should be accepted by all parties involved that it will take a few more years of research before we have useful benchmarking data.

In short, the SIG recommended a hybrid approach to surveying current digitisation practices, which on the one hand will not compromise the original goals of the Numeric survey (i.e. to get a better understanding - from a policy point of view - of the growth of and investments in digital cultural heritage) and on the other hand will appeal to the institutions to participate in their own interest. The three main topics of the Numeric survey (size, costs and usage of digital heritage) are the results of complex sets of activities and procedures, and the SIG assumed that most of the institutions are still trying to make these activities run smoother and more efficiently. By analysing the 'digital workflows' in the cultural institutions, not only more precise definitions can be obtained for surveying purposes, it

may also set the standards for improvement of the management of digitisation activities.
It should be noted that the Numeric Study was a new, even ground breaking initiative. It cannot be expected to have established an EU-wide understanding of relevant definitions and surveying methodology instantly. The strengthening of awareness of a common approach and shared definitions will be needed on a permanent basis in the follow-up activities to Numeric. More specifically, the SIG considered that the training of the national coordinators that are responsible for the translations and distribution of the questionnaire, was necessary to reduce the amount of misinterpretations as encountered in the responses to Numeric and thus reach wider harmonisation.
An example to illustrate this: as identified in the Numeric Study Report, the word 'digitisation' itself proved to be problematic. Numeric used the definition from the American Institute of Museum and Library Services: "the process of converting, creating and maintaining books, art works, historical documents, photos, journals etc, in electronic representation so they can be viewed via computer and other devices." This may look like an adequate definition from an authoritative institution, but responses to the Numeric survey showed that many archives and museums, for different reasons, tend to include the cataloguing of their collections in databases as part of what they call 'digitisation'. For museums digitisation has to a large degree been part of collection management. Archives create elaborate records with information on structures and relationships between collections and objects. For them, an EAD-record can be considered as a digital object that results from digitisation. The same has been observed for monuments: do we consider a digital record of a monument as digitisation, or do we only count digital reconstructions as such? In order to obtain valid statistical data about digital heritage, these kinds of definition problems need to be solved first.

4. THE DIGITAL FACTS (NETHERLANDS)

It was precisely this need for more research and tools to support the monitoring of digitisation, that made the Dutch Ministry of Education, Culture and Science (OCW) invest in a national project on digitisation intelligence, alongside Numeric. This project was called The Digital Facts (De Digitale Feiten), and was coordinated by the DEN foundation (Digitaal Erfgoed Nederland). In the first year of the project, 2008, the focus was on getting as much as possible valid data from heritage institutions to be submitted to Numeric. A project officer worked closely with an external company to create the Dutch equivalent to the Numeric survey. A lot of effort was put into assisting the institutions to compile their responses to the survey. This was quite time consuming, but it paid off. The Numeric survey addressed many topics and the questionnaire was quite extensive. As a result, several staff members from a single institution had to get involved and proper support was needed to persuade the institutions to complete the survey. In the end, over 130 institutions agreed to participate and an authoritative publication on the progress of digitisation of cultural heritage in the Netherlands could be created. Thanks to these good results and because of their commitment to this area of research, the Netherlands were asked by the European Commission to chair the Special Interest Group, SIG-STATS.
However, as in other European countries, it was felt that not all sections of the Numeric questionnaire were based on a solid methodology. The DEN Foundation identified three main areas for further research, and the Ministry of Culture agreed to invest in a continuation of the Digital Facts project in 2009. The three main areas were methods to measure 1) usage of digital heritage collections, 2) methods to calculate costs of digitisation projects and 3) methods to measure born-digital heritage collections. In 2009 three specialised project officers were responsible for setting up recommendations on these three area's for improvement of the surveying methodology.

4.1 Web statistics

The research on the usage of digital heritage collections focused on web statistics by cultural heritage institutions. Increasingly, cultural heritage institutions provide access to digitised resources on their websites and many of them present web statistics in their annual reports. Amongst other things, the statistics can show how often a website is visited, which pages are the most popular, via which pages people enter the website etc. But what methodology and tools are used to compile these statistics? Is the use of the digital collections expressed in these statistics? How reliable are the data, and is it possible to compare the statistics across institutions and over time?
The research resulted in two reports: firstly a literature survey was carried out to obtain insight in the backgrounds, feasibilities and limitations of web statistics. This led to a practical manual for the use of web statistics. One of the recommendations is to use 'visits' as the key concept in managing web statistics, not (unique) visitors or hits, as is frequently done. Secondly a report was written on the current use of web statistics by cultural heritage institutions in the Netherlands. As was expected, only a few institutions were really aware of the many pitfalls that come with web statistics and presented their data with care. To name such a pitfall: improvement of the navigation or usability of a website may result in lower numbers of hits in the statistics, but this does not mean less use of the website. It has become easier ('less clicks') for a user to find the information and this is without a doubt a qualitative improvement. By just presenting annual web statistics in a sequence, without any explanation, wrong conclusions might be drawn. As web statistics are becoming more and more accepted as an instrument for accountability towards funds or governments, it is imperative that we make better use of them.
The reports are published in Dutch, but an English summary was created by Europeana (see References).

4.2 Costs of digitisation

The research on better ways to calculate and express costs for digitisation projects led to the creation of an elaborate cost model that can be used for project budgeting. The core of the cost model was created by the Archives of the Province of Gelderland, for their own purposes. With the support of the DEN foundation, one of their staff members investigated whether the cost model could be used by other archives and, indeed, museums and other heritage institutions. The outcome was positive, and in April 2010, the Gelders Archief and DEN were able to present the fully developed cost model, accompanied by an extensive manual.
The cost model is set up as a spread sheet, in order to give the heritage institutions full flexibility to adjust the model to their own needs. The cost model is quite extensive, allowing institutions to understand better the costs of all activities that are needed to digitise a cultural heritage collection: physical analysis, transport, adding metadata, the actual digital reproduction through scanning or photography, quality control, storage, promotion et cetera. At the moment, the model is still being tested. If the model will be accepted widely, it will not only support harmonisation of terminology on costs, it may also support the automatic exchange of benchmarking data, if institutions are willing to share their own cost calculations.

The DEN foundation hopes to present an English version of the model in 2011.

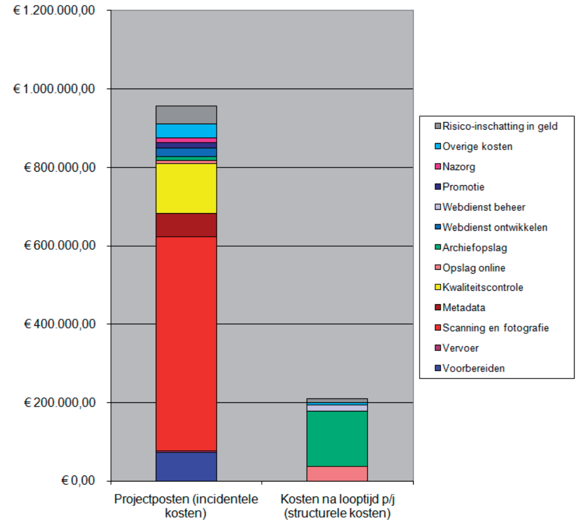

Figure 3: An example from the DEN cost model, based on a large scale news paper digitisation project. The graph projects the overall costs during and after the project lifetime, distributed across various cost categories (e.g. metadata, storage, promotion and transport).

4.3. Born digital heritage.

The third main area of research in the Digital Facts project was born digital heritage collections. This topic was not covered by Numeric, as Numeric focused on the conversion of analogue collections to digital objects. This exploratory study as part of the Digital Facts project was designed to map out specific problems of managing and measuring born-digital heritage at selected Dutch heritage institutions.

As this was really new ground, it was decided not to do a wide survey, but to focus on the heritage institutions that were considered to be pioneers with born-digital heritage materials. How do they manage and measure their collections? What problems do they encounter? In total 29 institutions participated actively. The study showed that most of their collections contain both digitised and born-digital material, that both are managed in the same system and even that it is not common to make a distinction between born-digital material and digitised material.

However, it is recognized that there are differences in acquisition, metadata and digital preservation. This is where an underlying problem surfaces. Most of the organisations only add large quantities of born-digital object types with a traditional and/or digitised counterpart to their heritage collections, such as photos, videos, audio files, e-books and e-articles. New forms of born-digital heritage, meaning objects without a traditional or digitised counterpart, are not collected or are only collected in dribs and drabs. Examples are websites, games, 3D designs or digital reconstructions.

As a result, the majority of the institutions states that interesting Dutch born-digital heritage material is being lost because it is not or not sufficiently collected, due to a lack of priority, funds, knowledge or technical facilities. There is a great need for best practices and a clear allocation of tasks among various institutions.

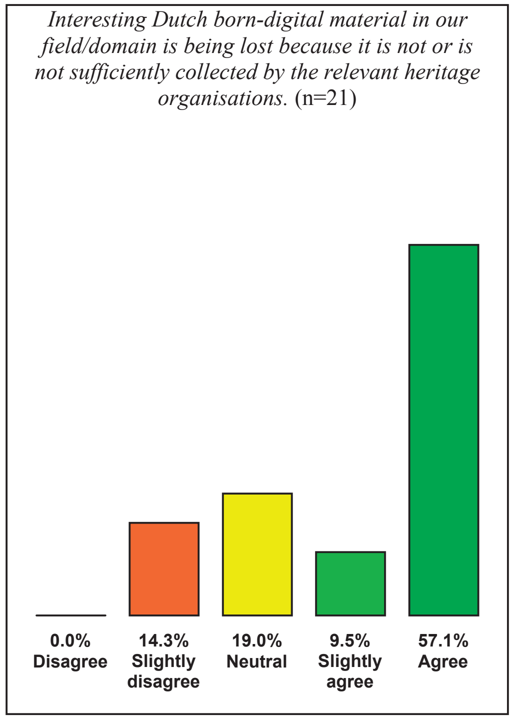

Figure 4: Graph from the report on Dutch born-digital heritage, showing that the majority of institutions agree on the fact that born digital heritage is lost due to an unclear allocation of tasks among cultural heritage institutions.

The results of these three Dutch research projects will most likely feed into a new European project that is currently in the making: ENUMERATE.

5. ENUMERATE

The Numeric project ended with the publication of the Study Report as a PDF-document. There is a wealth of information stored in the document, but the data and the graphs cannot easily be re-used or updated. SIG-STATS addressed this issue, and would very much like to see the emergence of a data repository, where statistics and other data on the digitisation of cultural heritage are not only available in static documents, but also as dynamic data that can be submitted, retrieved and visualised. Such a repository could be a valuable platform to promote networking, collaboration and knowledge-sharing about the statistical monitoring of digitisation of cultural heritage. As such, it could be an important tool to support the growth of Europeana, by providing up to date intelligence about all the content that could feed into Europeana.

In the spring of 2010, SIG-STATS decided to set the first steps towards such an data repository, by drafting a project proposal for a follow up project to Numeric. While preparing a project proposal for the Thematic Network under the Digital Libraries theme of the EU ICT Policy Support Programme, other parties notified the SIG that they were interested in participating. These included governmental organisations or companies from Hungary, Slovenia and Spain. CollectionsTrust from the UK was invited to become the coordinator of the proposed project, to be called ENUMERATE. Together with the six original participants in the SIG-STATS, this consortium aims at a lasting transformation in the availability, quality, accuracy and relevance of statistical data about digitisation, digital preservation and online access to cultural heritage. The main objectives of ENUMERATE are:

- The development of a vibrant and sustainable European **community of practice**, connecting practitioners in statistical analysis and digital content creation and preservation and supporting the sharing of knowledge and best practices.
- The creation, promotion and development of a statistically valid **open methodology** for surveying the digitisation, use and preservation of cultural heritage materials in Member States.
- The implementation of a multi-annual programme of coordinated **surveys** based on this methodology, including wide-scale harmonized statistical data-gathering and more in-depth and analytical surveying of digitisation activities by European cultural heritage institutions.
- The creation and maintenance of an open, sustainable **data platform** to collate, analyse and promote the use of the normalized data and intelligence arising from these surveys.

At the time of writing, the ENUMERATE proposal was reviewed positively by the evaluation committee of the ICT-PSP Digital Libraries theme, but negotiations with the European Commission are still to take place. It is hoped that ENUMERATE will start in January 2011.

6. CONCLUSIONS

Both the heritage institutions and governments at various levels have a growing need for more accurate and up-to-date intelligence on the digitisation of cultural heritage. Many parties consider the transition from analogue to digital culture a landmark activity of our time, but speeding up this process requires large-scale, coordinated efforts across Europe, within Member States and between individual institutions and networks. Better data on the size, costs and use of digital heritage is needed to track impact, to identify and celebrate success, and to define policies and funding instruments to target specific issues or opportunities.

The NUMERIC project estimated that the annual value of dedicated digitisation budgets of cultural institutions in Europe added up to a total of 261 million euro (Numeric Study Report p. 69). The majority of the costs of digitisation and digital preservation are funded through public subsidy. This represents a real-terms investment on behalf of European citizens of many millions of euro every year. More quality data on the output of these digitisation efforts contribute to a better accountability to society at large.

However, there is not yet a strong tradition in gathering statistical data on digital heritage. There is no clear cut methodology to do so on a regular basis. The NUMERIC project was a ground breaking effort to set a new standard for this type of intelligence. Some satellite activities, such as SIG-STATS and the Digital Facts project in the Netherlands, contribute to the evaluation and further development of the outcomes of the NUMERIC project and to the creation of a base that is useful for future benchmarking.

The projects described in this short paper are, together with other related projects and activities, proof that there is a growing commitment to the development of methods and tools to improve our knowledge about digitisation activities and their output. If we are to create sustainable models for digital heritage services, such intelligence will prove to be crucial in the strategic decision-making by any party involved at European, national or institutional level.

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CULTURAL HERITAGE POLICY DOCUMENTS AND THEIR PARTICULAR RELEVANCE TO THE MEDINA FORM

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KEY WORDS: Cultural heritage, policy documents, Arab States, Medina

ABSTRACT

World heritage properties are located in five regions according to the UNESCO World Heritage Centre. Europe and North America are privileged in having around 50% properties; while the Arab States have only 7%. The Arab countries on the Asiatic and North African Mediterranean region are blessed with an extraordinary cultural patrimony. However, the relatively low economic base, fractured historic centers and inappropriate interventions are the main dilemmas facing safeguarding these areas. Numerous documents approved by UNESCO, ICOMOS and such organizations have been the main international guidance, and most of them are yet applicable at the European level.
This paper is an investigation into the position of recommendations concerning this region. It is revealed that the context of these has received relatively scant attention; additionally, there is a lack of effective guidance to address current problems. This study concludes that a more precise consideration should be given to guide contemporary interventions relating to heritage fabric.

1. INTRODUCTION

A study of the conservation movement would inevitably highlights strong links between the establishment of a continual stream of cultural heritage policy documents and various innovations in the practices of heritage conservation. Additionally, the legislative framework for the protection of heritage environments has resulted in a number of procedures that have been a subject for criticism. It is not only that the classification of heritage values has proved to be a very complex practice, but also the assessment of new architectural interventions within heritage settings has been one of the most debated issues in urban design. The investigation reported here is part of a broader analysis of over one hundred cultural heritage policy documents covering the rest of the world.

As early as 1877, the awareness of the values of historic monuments and the destruction caused by inappropriate conservation and architectural introductions saw the *SPAB Manifesto 1877* as an agreed procedure for providing conservation guidance at the UK and European levels. While the importance of protecting the values of ancient properties and areas saw the proliferation of the Athens Charter 1933 as an appropriate legislation for protecting common heritage at the international level.

2. WORLD HERITAGE PROPERTIES

The UNESCO, as the main body for all issues related to world heritage properties, divides the list of these patrimonies into five regions related to its activities, and do not necessarily reflect the actual geographical locations. See Table 1.

From Table 1; it is clear that Europe and North America dominate with around 50% properties on the World Heritage List; while the Arab States count for only 7%. However, the heritage cities of the Arab States at the Mediterranean Basin are fortunate to be the location of what is often called the *Medina(s)*, which are particular type of medieval Islamic cities.

The *Medinas* are important not only for the built physical structures, but also for the typical urban fabric associated with them, and they have particular qualities that should be preserved. These *Medinas* have been facing many dilemmas; some of the most pressing are:

(i) Failure in sustaining the meaning of the place;
(ii) Absence of readily available evidence of the benefits of investing in heritage;
(iii) Vacant pockets of land and collapsed buildings; however, provide the potential for contemporary architectural interventions.

Region	Cultural	Natural	Mixed	Total	%	No. of States parties
Latin America & the Caribbean	83	35	3	121	14%	25
Europe & North America	375	56	9	440	49%	49
Asia & the Pacific	129	48	9	186	21%	28
Arab States	60	4	1	65	7%	16
Africa	42	33	3	78	9%	29
Total	689	176	25	890	100	148

Table 1. The number of World heritage properties by region according to the UNESCO.
Source: http://whc.unesco.org/en/list/stat#s1, accessed 30/07/2010

3. CULTURAL HERITAGE POLICY DOCUMENTS

On the international level, the leading organizations UNESCO and ICOMOS along with various international, national and Non-Government associations have authorised numerous publications of documents promulgated as charters, conventions, recommendations and such formats, which covered various aspects of conservation, protection and safeguarding practices. Notwithstanding the contribution of such publications into identifying, conserving and sustaining heritage values in respect of various methodologies, a number of limitations are underlined. These shortfalls are often addressed by some documents or by other studies. For example, despite the wide range of the subjects covered by hundreds of charters and conventions, the issues of assessing new architectural interventions within heritage settings are not yet fully incorporated. Additionally, in spite of the international applications of most of the documents, there is a considerable concentration on the European context in particular. This is acknowledged by the recent review of the *Venice Charter 1964*. The review was in 2007 by INTBAU to shed the light on two major issues: the lack of appropriate guidelines to efficiently assess the introduction of contemporary architecture within heritage context, and the limitation in the document's application. The Charter stated that "It has also been noted that the Venice Charter did not sufficiently address challenges beyond Europe and the United States, and overlooked the vital role that traditional building crafts continue to play. Lastly, a number of logical contradictions have become evident within the Charter itself, or within its over-rigid interpretation".

3.1 Conceptual Analysis of the Documents

In an attempt to investigate these issues, this study adopts a systematic analysis that is applied on a range of selected documents according to the following criteria:

Subject
1. Documents for safeguarding the main categories of cultural heritage properties: a single building, a group of buildings and a town.
2. Documents for safeguarding other types of cultural heritage that are related to the main categories: intangible heritage, archaeological heritage and cultural landscape.
3. Documents that present recommendations for introducing contemporary architecture in cultural heritage settings.

Application Level
1. Documents which are applicable at the international, European, or North African and Asiatic Mediterranean levels.

Organisations
1. Documents authorised by UNESCO, ICOMOS, and well established international organisations.

It is important to note that this paper is part of a broad research aims at developing an assessment model based upon a consistent and comprehensive technique for assessing contemporary projects inserted in a heritage setting; in terms of safeguarding all values associated with such heritage in a sustainable approach.
An investigation into cultural heritage documents issued from 1931 to 2010 by (ICOMOS, UNESCO, OWHC, EUROPA NOSTRA, International Congresses and Symposiums, ICCROM, CIAV and INTBAU), and in line with the above stated criteria has led to a list of 81 documents (see Figure. 1).

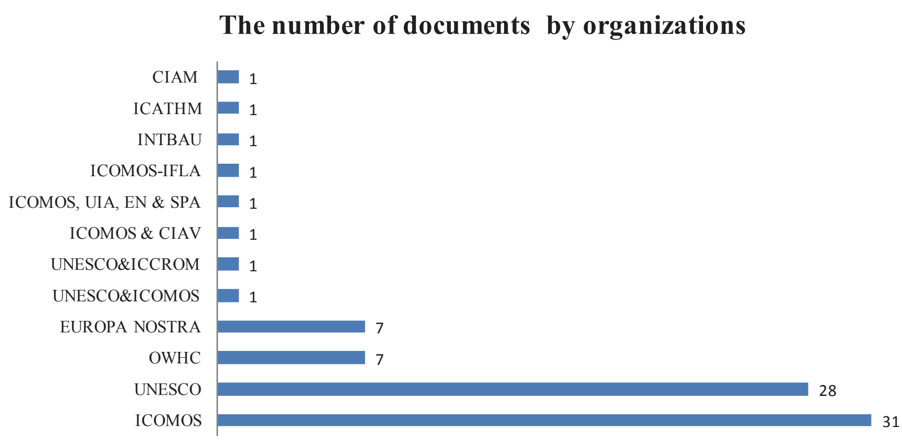

Figure 1: The number of documents classified by their authorizer organisations

The *Vienna Memorandum 2005*, which is one of the significant international documents, also underlined the importance of these vital issues. The charter recognized the drawback in providing clear definitions of the conservation principals that led to inappropriate practices articulating that "The expanding notion of cultural heritage in particular over the last decade, which includes a broader interpretation leading to recognition of human coexistence with the land and human beings in society, requires new approaches to and methodologies for urban conservation and development in a territorial context. The international charters and recommendations have not yet fully integrated this evolution".

The analysis of the documents reveals that within this numerous range of instruments, only four documents address issues related the context of the Arab States at the Mediterranean region in particular. See Table 2. It is important to acknowledge that the *Fez Charter 1993* addresses world heritage cities in general, but it is included in this classification as it is issued in the light of safeguarding North African cities. It is also important to note that there is a current framework that is the *Mediterranean Heritage, a Project for the Future 2008-2012* aims at safeguarding and valorising the cultural heritage of the Mediterranean region.

Document's Title	Organisation	Date
1. Recommendations of the Executive Committee Concerning Special Problems relating to the Reclamation, Restoration and Development of the Potencialities of the North-African and Asian Cities of the Mediterranean Basin.	ICOMOS	1968/June
2. The Fez Charter: Charter of the Organisation of World Heritage Cities.	OWHC	1993/Sep.
3. Appeal for the protection of cultural property in Israel and Lebanon.	Europa-Nostra	2006/Aug.
4. Charter on the Safeguarding of Palestinian Historic Towns and Unban Landscape.	UNESCO	2008

Table 2. The documents addressed the heritage issues of the Arab States Mediterranean region

From Table 2, it is clear that these particular documents were issued in a time frame spanning 40 years and authorised by different institutions. Additionally, these instruments address a number of diverse topics including: restoration, protection, and safeguarding cultural heritage assets. While the other 77 documents address broader contexts at international and European levels. It is also notable that the contribution of UNESCO and ICOMOS is very limited in addressing current and urgent issues facing the conservation and developing practices of significant heritage in this region.

The systematic conceptual analysis applied on the texts of each document, according to particular set of criteria, reveals that each of the above mentioned documents notes the exceptional values attached to such heritage. For example, the initiated Recommendations assert that "These historical sites are, in effect, a fundamental and irreplaceable part of the cultural heritage of humanity". At the same time each of them addresses particular values associated with cultural heritage properties.

Challenges facing the safeguarding process, along with offering recommendations for a number of conservation practices such as restoration, protection, safeguarding and development are also indicated in these cultural policy instruments. As stated earlier, this study is a part of a wider research that identified 12 values associated with cultural heritage properties. In an attempt to examine these 4 documents against addressing the set of the identified values; it was recognised that notwithstanding the focus on cultural, social, physical, historic and identity merits, a number of vital values found in documents relating to other regions were often disregarded, such as Outstanding Universal Value (OUV) and economic values. See Table 3.

Key challenges facing safeguarding and developing heritage assets, along with promulgated recommendations were also indicated in these documents. Armed conflict, economical and social pressures, along with urban development that might destroy the significant characteristics of the valued fabric were underlined, "…economic and social changes are liable to bring on the irreparable deterioration of urban structures, and of architecture which, though of the highest quality, is fragile and complex, and that the greatest care must thus be taken to preserve the fabric and internal and, external structure of such works". While the most significant recommendations advocated by these documents highlighted the importance of international cooperation and recognition of such heritage, furthermore the *Recommendations 1968* and *Charter 2008* proposed particular advices for urban areas and heritage zones in terms of sustaining their heritage and managing the development of contemporary architectural structures in and around these areas "Control the transformations, improve the architectural quality and reduce the heights of proposed buildings in the buffer zones".

4. CONCLUSION

This focussed review relating to cultural heritage policy documents in the *Medina* region clarified the main aims of these instruments for safeguarding and managing the world heritage. The importance of the cultural heritage properties accommodated in the Arab States at the Asiatic Mediterranean Basin is also acknowledged. Current guidelines give insufficient consideration to this particular context. They however shed the light on the current continuing challenges facing the preservation of the originality, and the sustainability of this inheritance.

The relative paucity of documentations reveals and confirms the critical need for developing useful and appropriate legislations to be approved by the leading institutions. Better instruments to manage the protection, safeguarding and conservation practices in this particular region are urgently needed if the heritage sites are to be protected in an appropriate way. New documents also need to address issues such as Outstanding Universal Value and Economic Value more comprehensively.

Documents	VALUES											
	Cultural	Social	Physical	Historic	Identity	Human	Integrity	Aesthetic	Authentic	Intangible	Economic	OUV
ICOMOS 1968	■	■	■	■		■		■	■		■	
OWHC 1993	■	■	■		■	■	■			■		
Europa Nostra 2006	■	■	■	■	■							■
UNESCO 2008	■	■	■	■	■		■	■	■	■		

Table 3. Shaded Boxes indicate values addressed by the Arab States Mediterranean documents

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EuroMed2010
3rd International Conference dedicated on Digital Heritage
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EUROPEANALOCAL REPRESENTING LOCAL AND REGIONAL CONTENT IN EUROPEANA

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KEY WORDS: Europeana, EuropeanaLocal, local and regional, digital content, cultural institutions, metadata, aggregations, infrastructure

ABSTRACT:

This paper describes the vision, objectives, work and outcomes of the EuropeanaLocal Best Practice Network funded under the EU CIP programme (ICT-PSP). It outlines the way in which EuropeanaLocal partners have been able to make a substantial contribution of about 30% off the total content required to fulfil Europeana's target for its 2010 Rhine release, together with the contribution which EuropeanaLocal is making and plans to make in its final year to the development of a sustainable infrastructure which incorporates local and regionally sourced digital content and proposes some needs for continued work in the future.

1. INTRODUCTION

Europeana, the flagship development under the European Digital Libraries Initiative is, with its 'Rhine' release in summer 2010, to be followed by the Danube release in 2011, progessing by stages from its prototype phase towards becoming a major operational cultural service, responsive to the needs of general users throughout Europe.

Hitherto, Europeana has been built upon the coordination of a growing number of projects and Best Practice Networks (BPN), funded mainly under the European Commission's ICT-PSP programme within the CIP framework, now amounting to some 20 individual projects

Among this 'family' of projects, EuropeanaLocal is a BPN, running for 3 years from June 2008, which has set out to demonstrate the value of the contribution which digital content sourced by cultural institutions at the local and regional level, can make to Europeana. The project was originally named EDLocal, but this was changed after the start to its current title, in order to be consistent with the, at that stage, recently decided Europeana brand.

The results of the first two years of this activity have met with a high level of success. Of the 10 million metadata records for digital objects indexed by Europeana for the Rhine release, some 3 million have been contributed by the proportionally small sample of local and regional organisations participating in EuropeanaLocal, the great majority of them during the first part of 2010, a period which has seen total content accessible through Europeana grow from about 4.6 million objects to 10 million. An important effect of this has been to significantly broaden the base of countries from which content is visible through Europeana.

It should here be noted that the Europeana model predicates that the digital content itself remains on its host site and that Europeana harvests, indexes and links to it where it is. The OAI-PMH protocol is at the core of this system in terms of metadata transportation and gradually this is becoming predominant over other approaches to ingestion within the Europeana 'universe'. Its use was accepted as a starting point by EuropeanaLocal and is a fundamental of the infrastructure which it has put in place.

This paper describes the main aims of EuropeanaLocal, outlines the work being carried out to achieve them and summarises the results to date. It goes on to assess the prospects for a sustainable infrastructure of 'harvestable' aggregations across Europe which include the metadata for local and regional content, in the context of: what EuropeanaLocal is setting out to achieve in its final year; and of the challenges which need to be addressed to maintain upscale its work, once the project is finished.

2. EUROPEANALOCAL: GOALS AND RESULTS

2.1 Rationale and objectives

EuropeanaLocal's underlying premise is that insufficient attention had hitherto been paid, in the context of Europeana, to the potential of digital content created and held by cultural institutions (public libraries, small museums, local archives etc) operating at local and regional level. The focus had, perhaps naturally, been mainly upon the impressive collections of larger institutions and the relatively few national cross-domain aggregations in EU countries.

This impression is borne out by the August 2009 content survey carried out by Europeana which showed that only 5 countries contributed more than 1% of the content available through Europeana and that 47% came from a single country, France. Ingestion from EuropeanaLocal partners during the first half of 2010 has played a significant role in redressing that initial imbalance.

Survey work carried out at proposal writing stage indicated that even from the limited sample of partner organisations included in the EuropeanaLocal consortium (see2.2 below), well over 20 million items of digital content could be identified. Subsequent work within the project has led to a substantial whittling down of this figure for a number of reasons, including harmonisation of the metric basis for counting (originally, partners did not use a consistent basis of item 'units' for counting) and the exclusion of metadata records not linked to digital content e.g. library catalogues. Nevertheless, as described above, what remains has provided a striking and substantial contribution to Europeana's early content targets. Furthermore, by spreading the basis of *locality* among Europeana source content, it can be argued quite strongly that a service which is more geographically representative of European culture is likely to be attained.

Given Europeana's necessary ambition to maintain at a manageable level the number of aggregations across Europe from which it needs to ingest metadata and to handle the communicative relationships accompanying that process, EuropeanaLocal recognised at the outset the challenge which would arise from any need to harvest metadata from repositories situated in a vast number of localities across Europe. Hence the notion of encouraging as far as possible a 'sensible level of aggregation' infrastructure in each member state was part of the original vision of EuropeanaLocal.

However, at the outset the position among member states was characterised by a high degree of fragmentation of approach. In a few countries (France, Germany, Italy, Norway, UK) local and regional content from some institutions was aggregated on a cross-domain basis at national level. Elsewhere (Ireland, Latvia, Spain, Sweden), the emphasis was more upon national aggregation of content from a single domain, most frequently but not always the libraries domain. In some countries (e.g. Belgium) the region is the highest level of aggregation.

In a comparatively large number of states, aggregation initiatives involving local and regional content were non-existent or vestigial, a challenge critical to the sustainable future development of Europeana which EuropeanaLocal has begun to play a part in addressing. In this context, it should perhaps be remarked that large national cultural institutions have comparatively rarely carried out aggregation of content or metadata from smaller institutions and the juxtaposition of national and institutional interests remains an issue to be resolved. Contrasting and incompatible approaches between large scale digital library initiatives previously funded at European level, for example between 'collection-level' descriptions and the 'item-level' approach firmly adopted by Europeana have also introduced hindrances, albeit transient, to progress, but from which important lessons have been learned.

2.2 The network partner group

The group of partners identified as participate in the EuropeanaLocal Best Practice Network, which can perhaps most usefully be considered a 'proof of concept' somewhat reflect this fragmented situation. The fundamental rationale for their inclusion was that within the timeframe available to the compilers of the proposal, wherever possible, there should be at least one organisation per EU member state with a significant track record or proven interest in the practical provision of local and regional content or its aggregation.

The outcome was that such an organisation was identified in every member state except Luxembourg, but that the nature of these organisations varied greatly between countries and included: 1 Ministry of Culture, 2 national libraries, 2 national museums, 3 national cultural agencies (all the foregoing in their capacity as aggregators of local and regional content); 5 regional cultural authorities; 7 public library services; 1 local museum, 1 research foundation, 1 regional digital library provider and 3 private sector organisations. In essence, each of these organisations either was or has become an aggregator of some shape or size, since in no case is a partner responsible for only a single collection repository.

In addition, the Europeana Foundation itself, MDR Partners (the scientific coordinator and project manager) and two technical partners: Asplan Viak (Norway) and EEA (Slovak Republic) make up the network consortium. ABM-Utvikling, NO is a technical and service adviser, with a special responsibility for evaluation.

List of Content Providers by country

Angewandte Informationstechnik Forschungsgesellschaft mbH, AT
Provincie Limburg, BE
Public Library 'Pencho Slaveykov' (Public Library of Varna), BG
Cyprus Research and Educational Foundation, CY
Cross Czech a.s., CZ
Roskilde Kommune, DK
Eesti Rahva Muuseum (Estonian National Museum), EE
Ministry of Culture, Spain, ES
City of Helsinki, FI
Zentral- und Landesbibliothek Berlin, DE
Conseil Général de la Gironde, FR
Veria Central Public Library, GR
Bekes Megyei Tudashaz es Konyvtar, HU
An Chomhairle Leabharlanna - The Library Council, IE
Regione Marche, IT
National Library of Latvia, LV
DIZI UAB, LT
AcrossLimits Technologies Ltd., MT
Erfgoed Brabant, NL
Instytut Chemii Bioorganicznej
PAN - Poznańskie Centrum Superkomputerowo-Sieciowe, PL
Fundacao Museu Nacional Ferroviario, PT
Biblioteca Judeteana "Octavian Goga" Cluj, RO
Slovenské národné múzeum (Slovak National Museum), SK
Narodna in univerzitetna knjižnica, SI
ABM Resurs/Stiftelsen Länsmuseet Västernorrland, SE
Collections Trust, UK

2.3 Work in the first two years

The work of EuropeanaLocal in the two years since June 2008, has followed a series of steps common to partners, although considerable variations in national and regional situations, including the extent of prior knowledge and the availability of skills, have needed to be taken into account.

Content and metadata survey. The initial 'count' of digital objects available via each partner (in the proposal document) was validated through a structured online content survey which covered in greater detail aspects such: as collection themes, time periods and languages; number of digital objects and the availability of their 'thumbnails'; numbers of objects in each of the broad Europeana-defined formats; metadata standards used or adapted; geographic terminology, time and date formats; subject terminology; use of unique identifiers; use of OAI-PMH or other search protocols and other aspects. This allowed a more refined quantitative identification of which items were eligible for inclusion. During the course of the second year an 'Event Log' was introduced enabling all partners to submit online, numbers of items involved in various stages of the process leading up to ingestion by Europeana. The Evens Log has been simplified somewhat in the light of initial experience.

Implementation of an OAI-PMH compliant repositories. infrastructure. Following the initial analysis of which partners already had such metadata repositories in place, software options were identified and evaluated. Repox and PKP Harvester software were recommended, although the technical partners were also able to provide some technical support for installation and initial population of Celestial and Fedora repositories. Technical training and support was then provided to enable each partner to install its chosen repository software.

Metadata normalisation. A wide variety of native metadata schema is in use by the cross-domain partner group of EuropeanaLocal. Effective discovery of content within Europeana currently requires 'mapping' of native schema to the ESE (the Europeana Semantic Elements). Each partner was required to complete such an exercise. ESE is the Europeana current data model which consists of the Dublin Core (DC) metadata elements, a subset of the DC terms and a set of twelve elements which were created to meet Europeana's functionality needs. Content providers also need to supply: a link to the digital object's location online; and a 'thumbnail' of the object.

Harvesting and ingestion. During the second year of the project, Europeana has begun the process of harvesting and indexing content from a majority of the Europeana Local partners in preparation for its Rhine release. Partners have been able to review the results before the finalisation of the process, using a Europeana tool called the 'Content Checker', a webtool for data providers to ingest Europeana Semantic Element (ESE) data in a test environment to check and validate the status of their data, used for the formal submission of the data to Europeana.

EuropeanaLocal partners make use of this tool for testing and validation purposes of the data they provide to Europeana. A link to the Europeana test portal can be shared with their own local group of content providers for quality control purposes.

Technical support and training workshops. The steps in the above process have been supported by a series of workshops in a variety of venues (Bratislava, Limburg, Ljubljana, London and Madrid) organised by the project's technical partners. These have proven to be important activities in ensuring a consistent level of knowledge among the partners.

Several technical requirements, guidelines and documentation have also produced by the Europeana office to assist content providers and aggregators with their content provision to Europeana, and to make sure the content is interoperable and complies with Europeana standards, including:

- Europeana Semantic Elements Specifications
- Metadata Mapping & Normalisation Guidelines
- Europeana Semantic Elements XML Schema
- About Europeana Semantic Elements XML Schema
- Technical Report: Archival Digital Object Ingestion into Europeana (ESE-EAD harmonisation)
- Guidelines for using EuropeanaLabs
- Europeana Data Model

Work with users. Europeana Local has integrated the work originally foreseen on usability testing with that of Europeana's mainstream activity in this area. In this way, it is drawing upon the specific expertise of its partners and their access to Europeana's target audiences at local level to provide both validation by content providers of the specification for the Rhine release and evaluation of the user interface and its functionalities by groups of end users, within the framework of Europeana's overall cross-project framework for activity in this area.

National meetings. The process by which Europeana Local is supporting the establishment of an effective and sustainable infrastructure of aggregations, involves the organisation of one or more 'stakeholder' meetings in each country. The agendas of these meetings are primarily designed to move forward the national aggregations agenda from its current position towards one which reflects Europeana's goals regarding a manageable infrastructure. The meetings also provide a more general opportunity to disseminate the work of EuropeanaLocal to an audience of content providers, aggregators and decision makers with an interest in Europeana.

During the second year of the project such meetings have taken place in Belgium, Czech Republic, Bulgaria, Portugal, Romania and Sweden and a programme covering every participating country has been drawn up for the remainder of 2010.

2.4 Results to date

Whilst the first year of EuropeanaLocal focused primarily on preparation activities, the second has mainly been focused on implementation. As reported above, the impact of the availability of content from EuropeanaLocal has had a very significant impact on the Europeana service. By the time of the Rhine release, about 30% of the content in Europeana will have come from EuropeanaLocal, making it the largest current source of content for Europeana and meeting its anticipated content target at this stage of its workplan.

By 16 July 2010, Europeana had 'ingested' and made visible through its main user interface some 3,014,971 items, from 15 of the 26 partner countries in EuropeanaLocal, broken down as follows by country.

1,136,306	Spain
636,911	UK
636,068	Norway
349,882	Poland
81,752	Sweden
53,854	Greece
38,315	Slovenia
37,953	Germany
12,686	Slovakia
12,016	Bulgaria
9,072	Slovakia
7,731	Lithuania
1,904	Austria
424	Czech Republic
97	Finland

Table 1. digital objects in Europeana from EuropeanaLocal by country, 16 July 2010

In achieving this, EuropeanaLocal partners have successfully installed or utilised a range of different OAI-PMH compliant repository software products and have successfully mapped and normalised a wide range of different metadata schemas to ESE including. This process has demonstrated the technical feasibility of putting in place a distributed infrastructure throughout the whole of Europe which would serve the basic requirements of Europeana for content.

The evidence from the first set of national meetings, which have been attended on average by about 100 stakeholders, is that significant impact can be achieved through discussion between national 'players' to prepare the ground for national aggregation initiatives which more comprehensively incorporate local and regional content than at present. The meetings in Bulgaria, Portugal and Romania in particular were possibly the first public occasions when this issue had been aired and provided an important opportunity to place it on the national agenda. Encouraging possibilities have arisen in each case a result. In some cases, it has been decided to organise a second meeting to follow up within the duration of EuropeanaLocal.

2.5 Goals and activities for the final year

The third and final year of EuropeanaLocal is an equally crucial period in the work of the Best Practice Network. The network wishes to do all it can to assist Europeana to meet its quantitative targets for the Danube release in 2011. At its outset, EuropeanaLocal set itself a target of 10 million items by the end of the project. It is not clear at this stage whether it will be possible to meet this target (equivalent to the entire content of Europeana at the time of writing). The number of imponderable factors involved makes it impossible to calculate what will be ingested in the final year with exactitude, although steps are being taken to clarify this where at all possible.
Among the avenues available are:

- content already identified from the remaining 11 partner countries;
- additional content made available through each partner's aggregation (numerous new content providers wanting to join Europeana are directed to EuropeanaLocal and its partners);
- newly-available content from national aggregations which EuropeanaLocal has played a role in establishing or extending.

Mechanisms for counting this content are not all easily available, in particular the last one listed. The Evaluation Working Group of Europeana Local is planning to introduce a survey-based methodology to achieve this.
The eventual implementation by Europeana of a regular reharvesting process will be a highly important initiative in ensuring that the representation of partner content is kept up to date.
Other developments emerging from Europeana and its core technical projects with implications for EuropeanaLocal during its concluding period include:

- the provision of subject vocabularies available at the local and regional level and their 'skosification' to enrich the semantics of Europeana;
- the consequences of Europeana's policies on content and IPR, including documents already in circulation such as its data agreements for content providers and aggregators respectively;
- the introduction of the Europeana Data Model (EDM) to enable the strengthening of semantic applications in Europeana and management of the impact of this 'migration' on EuropeanaLocal partners.

In addition to the completion of its programme of national meetings and its work with Europeana to acertain user needs and responses, EuropeanaLocal will also carry out its own Impact Study to assess how the approach tested in the project has affected the operations and outlook of content providers and aggregators.

3. CONCLUSIONS

EuropeanaLocal will have provided two major inputs to the progress of Europeana: a highly important injection of content; a practical proof of the vision that the tapping of local and regional content sources are vital for it to achieve its mission; and progress towards the creation of the infrastructure of aggregations that Europeana will need to survive.
Yet, EuropeanaLocal does not in itself provide a sustainable solution. There is no pan-European aggregation of content left behind as a result of EuropeanaLocal other than that which Europeana is now able to harvest directly from the infrastructure created and promoted.
At present EuropeanaLocal partners and their associated data providers contribute content through a variety of aggregations, depending on the current state of play in their country. However, in the longer term it is envisaged that, as the aggregation landscape develops and matures, local and regional data providers will join Europeana by contributing content through nationally based aggregations, which might be either horizontal or vertical.
A number of initiatives currently exist to establish European domain based aggregations, to add that of The European Library (national libraries).Several of them, such as APENET (national archives), CARARE (archaeology) and European Film Gateway are emergent from 'Europeana family' Best Practice Networks. Initiatives are likewise underway to increase the number of national aggregations, both single domain and cross-domain.
The nature of the 'landscape' which will result from these efforts remains at this stage unclear: it seems probable that Europeana will need to engage with a 'mixed economy' of single and cross-domain aggregations in the foreseeable future.

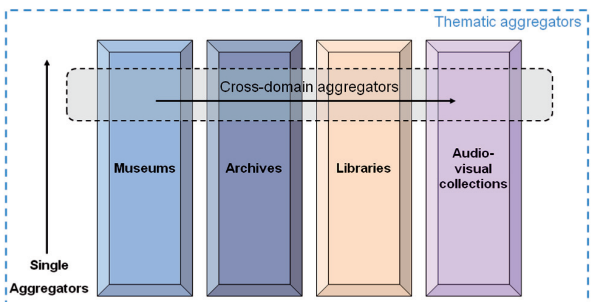

Figure 1: aggregation scenarios

The potential to mainstream and sustain an infrastructure which potentially encompasses all of Europe's regions and thereby makes a visit to Europeana an experience truly representative of the geographic scope of European culture, will require a continued and sustained effort of some magnitude, involving political will, funding and effective business practice and a willingness for cultural institutions at all levels to cooperate.
A major dissemination effort to create further awareness of Europeana and its potential importance to Europeans and to the cultural economy will be needed to drive this along.
As an early step, the Europeana Aggregator Handbook was made available in April 2010. The content of the handbook has been informed by the results of the aggregator survey which was performed in autumn 2009. The overall aim of the handbook is to provide sufficient information to aggregators that wish to submit data to Europeana and become sustainable partners of the service.

The Europeana Aggregator Handbook also includes the latest version of the Europeana Data Agreements. The document addressses the following subjects: administrative and organisational aspects of running an aggregator service; the workings of Europeana's Council of Content Providers and Aggregators; business and sustainability planning; technical and operational participation in Europeana; dissemination activities etc.

The Europeana Data Agreements finalised in April 2010 set out the contractual basis for organizations contributing data to Europeana. EuropeanaLocal partners, who have up until now been covered by a project wide agreement with Europeana, will move to conclude formal legal agreements towards the end of its project lifecycle (May 2011) in order to continue working with Europeana, either as an Aggregator or as a Data Provider as appropriate.

Two main agreements are involved:

- Data Provider Agreement – for single institutions providing metadata.
- Data Aggregator Agreement – for organisations which aggregate data from a number of different content providers.

Depending on which is most appropriate, the documents facilitate an agreement to be concluded either between an aggregator and Europeana or directly between a data provider and Europeana.

The Data Aggregator Agreement is based on a clean-hands model. That means Europeana does not sign agreements with individual content providers submitting data via an aggregator. The aggregator is responsible, if necessary, to clear rights with individual content providers in order to meet the requirements of the Data Aggregator Agreement with Europeana. The aggregator can use the Europeana Content Provider Agreement as a model in this situation.

Finally, while the overall concept that local and regional content providers have a key role to play in the future of Europeana in both a quantitative and a representative level, work remains to be done to demonstrate the quality of this content, for example in the particular sense that it enhances the thematic approaches envisaged by Europeana. This may become a focus of the final impact study of EuropeanaLocal.

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THE FINNISH NATIONAL DIGITAL LIBRARY PUBLIC INTERFACE

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KEY WORDS: Digital Libraries, Architecture, User interfaces, Digital Cultural Heritage, Usability, Data Harvesting

ABSTRACT:

The Finnish National Digital Library (NDL) project is a national project which improves online accessibility and usability of digital cultural heritage resources held by libraries, museums and archives in Finland by combining the services and collections of these organisations to a versatile user interface called the Public Interface. While focusing on common services, operational models and solutions the project will also prepare a plan for the long term preservation of digital cultural heritage materials.
The Public Interface will be an easy-to-use and versatile IR solution for heterogeneous digital resources. The architecture will separate the user interface from back-end systems. The operational principle is to keep cataloguing of data and digital objects in the back-end systems. Metadata will be harvested and indexed into the Public Interface for easy and fast information retrieval.
Understanding the end user needs has played a major role during the design process. Since the current portals are usually lacking in usability the aim of the National digital library is to enhance accessibility of digital resources through high usability and increased national funding on digitalisation.

1. INTRODUCTION

1.1 The National Digital Library of Finland

The Finnish Ministry of Education and Culture launched the National Digital Library (Kansallinen digitaalinen kirjasto, 2008-2011) project to improve online accessibility of information and usability of the digital cultural heritage material held by libraries, museums and archives, and to develop long-term preservation solutions (NDL, 2010). The NDL is closely related to other national cultural heritage portals, such as the German Portal zu Bibliotheken, Archiven und Museen (BAM, 2010) and the Swedish Open Cultural Heritage project (SOCH, 2010).
A total of 70 members from 35 organisations - ministries, national institutions responsible for preservation of cultural heritage, scientific and public libraries, museums, archives and representatives of other key interest groups - in five groups are participating in the National Digital Library project. Extensive committees coordinated by a steering group are supervising the development of the public interface and the long-term preservation solution.
The National Digital Library project has prepared a plan for the long-term preservation of electronic cultural heritage materials which underlines the need to boost competence and awareness regarding the digitisation of materials in libraries, archives and museums, as well as the availability of their electronic information resources and long-term preservation of electronic cultural heritage materials by providing funding, information, training and online services.
The National Digital Library is working in collaboration with the European Digital Library Europeana. This will ensure that the essential materials in Finnish libraries, museums and archives will also be available through Europeana.
The NDL was launched on summer 2008, the plan for the long-term preservation for the cultural heritage materials was published summer 2010 (LTP, 2010) and the public interface will go live in 2011. The project is funded by the Ministry of Culture and Education.

2. END USER NEEDS AND THE NATIONAL DIGITAL LIBRARY

2.1 Towards customer oriented services

According to research conducted in the Finnish memory organisation sector the end users are not satisfied with current library, archive and museum systems and services (Riikonen, 2006; Lukkarila, 2005). In our experience, several IR-services in use require the customer to take a training course before they can use these services efficiently. To make matters worse they have to use several different user interfaces and have to know which organisation is providing the desired services and collections. Commercial search engines are preferred to library search services, since the former are usually easier to use. The JISC findings on the Google generation stereotype also seem to suggest this (JISC, 2008). It seems our IR services should be organised in a more customer oriented way and their usability should be enhanced.

2.2.1 Heterogeneous users and usability

Due to heterogeneous user-groups, the Public Interface users will have varied expectations and needs. They will also share some common expectations, such as usability, reliability, wide range of content and relevant search results. Also, a single user may use the Public Interface in several roles: between scientific searches, a researcher may get acquainted with materials relating to his leisure interests.
To ensure that the end-user needs are met the NDL has prepared a usability plan which underlines the need for usability engineering during and after the project. Usability testing began with the identification of end-user needs and requirements by interviews of potential user groups. The usability will be further

tested during the piloting phase by heuristic evaluation of the UI and retrieval functionality. After the service goes live, usability will be monitored through regular user surveys and further heuristic evaluation.

Enhancing the electronic resource services will improve the prerequisites and the quality of research (Vakkari, 2008). Thus, the basic idea behind the NDL Public Interface design is to attain maximum accessibility and usability for end-users combined with high volume of digitised material.

3. THE NDL PUBLIC INTERFACE

3.1 Combined services

Currently, the end-user has to use several different services when searching for information, and to be able to choose the right service it is essential to know which organisation is providing the information and which collection holds the desired resources. The Public Interface is intended as a replacement for current interfaces to enable users to find the information they need through one interface, irrespective of which organisation is providing the information. Instead of using several parallel interfaces, it will be possible to adopt a single front-end interface to back-end system services. Such back-end systems include library systems, archival systems and museum collection management systems, long-term preservation systems, a metasearch service and digital archives.

3.2 Accessibility

Improving the accessibility of the current systems represents a challenge. Since such systems encompass not only user interfaces but also other services as one combined package, their development in a comprehensive customer-oriented manner has been difficult. In the Public Interface the operational principle will be to keep the front-end service and the back-end systems separate from each other. This will make it possible to develop the front-end service independently and regardless of the development of the back-end systems.

In contrast with the traditional metasearch (real time online search) common in most IR portals, the Public Interface service is based on centralised indexing (cf. Google). The index based searches are fast, and the results can be easily arranged to suit the end-user's needs, for instance, by facets such as content type or organisation. It will be possible to integrate the search functionalities of Public interface into institutional web sites, portals, electronic learning environments, social media services and other e-environments. Information retrieval services can thus be offered in customers own virtual working space as a widget or a plug-in for example. Since Finland is a bilingual country the service will initially be provided in the official languages, Finnish and Swedish, and an English user interface will be provided for international users.

4. CONTENT OF THE PUBLIC INTERFACE

4.1 Heterogeneous content

The content available through the Public Interface consists of the digital resources of libraries, museums and archives. Content can be digitised or born-digital objects (images, texts, sound files, video clips, e-publications) or reference data on physical objects (e.g. artefacts, museum objects, books, works of art, geographical locations) or other reference data stored in databases.

The Public Interface will provide unrestricted material for all users. It will also provide restricted access materials subject to user authentication, such as licensed materials (e.g. e-journals), archive materials with restricted viewing and use, legal deposit copies and other materials subject to copyright. Each organisation will be responsible for ensuring that the materials made available via the Public Interface are used in accordance with copyright.

The service will initially contain 50 million database references, hundreds of thousands of museum objects and photographs, more than 1.3 million newspaper pages, over 20,000 scientific journals, over 300,000 e-books, hundreds of thousands of documents and several million pages of digitised archive materials. The service content will grow through future acquisitions and digitisation initiatives.

5. FUNCTIONAL PRINCIPLE

5.1 Harvesting

The operational principle of the Public Interface is to keep cataloguing data and documents in the back-end systems. Metadata is automatically harvested from the back-end systems, normalised and indexed in the Public Interface to enable easy and fast retrieval (Figure 1.). Harvesting is based on standard OAI-PMH interface, built between different systems when necessary. In order for the searches to function, all harvested metadata must be normalised and indexed into an internal metadata format. This will take place in the format converter module of the Public Interface currently under development. We expect the module to be based on a modified PKP-Open Harvester System (PKP, 2010). The format converter will also provide conversions to other relevant formats used by third party systems, such as Europeana (Europeana ESE), when necessary.

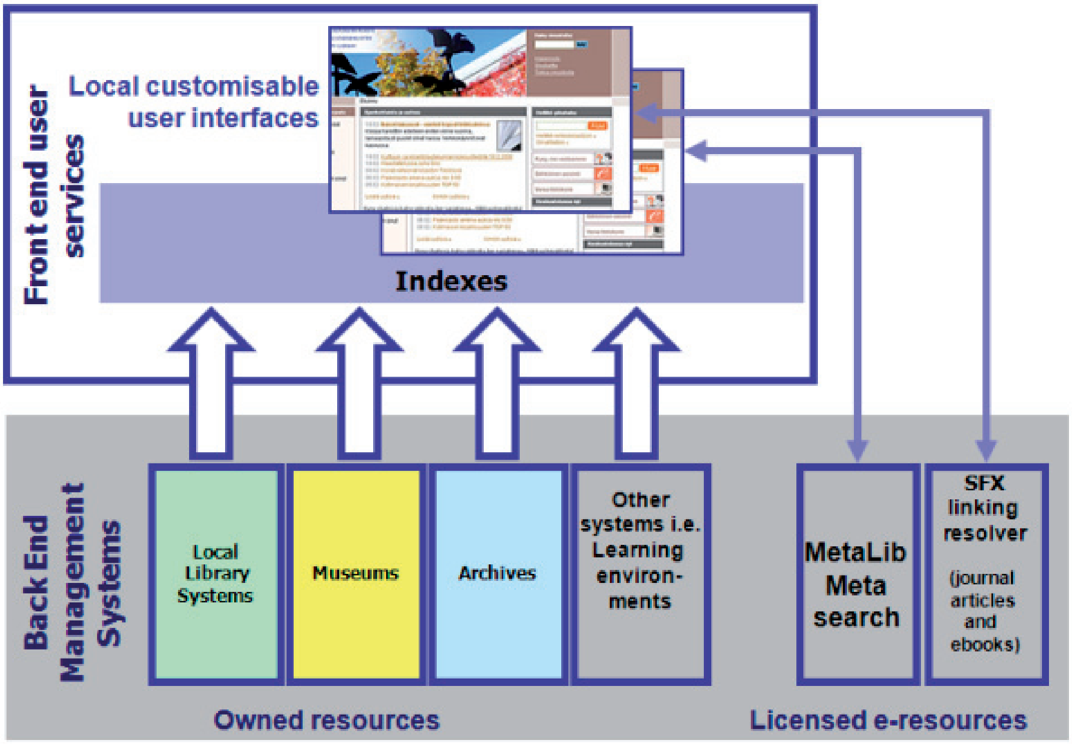

Figure 1: Functional principle and architecture of the Public Interface; the user interface separated from back-end systems

5.1 Normalisation

The normalisation of all harvested metadata to a single internal format will be a challenging task since the participating libraries, museums and archives use various standardised and non-standardised metadata formats which are extremely heterogeneous. Even systems using same formats might require their own normalisation rules because different cataloguing rules may have been used. Each different metadata format will require its own normalisation schemas and rules. A '*Pipe*' between the Public Interface and a back-end system will enable the metadata to be harvested and converted into the internal index of the Public Interface. After the normalisation schemas and rules have been built for each individual format and system and the '*Pipes*' are complete, harvesting, normalisation and index updating will function automatically and the customer will be able to access the most current information content.

It is not possible to index licensed electronic materials, e.g. e-journals etc. due to licensing restrictions. Instead, licensed electronic resources will be used via a centralised hosted index.

6. INTEGRATION OF SERVICES

6.1 One platform for all services

Organisations will continue to be responsible for the production (acquisition, licensing and digitisation), cataloguing and management of their own digital resources in their own back-end systems. Services provided by back-end systems will be integrated into the Public Interface, but this will require the separate APIs on the back-end systems. Other external third party services can also be integrated. Records can be enriched, for example, via book cover images from Google Books and LibraryThing and customers can create reference lists with a reference management tool (RefWorks, Zotero etc.). Records and record lists can also be exported to virtual learning environments.

There will be a single installation of the software with institution-specific views. Institutions will be able to customise the Public Interface for their own unique requirements – they can add and organise their own resources and impress their brand by logos and colours.

It will be possible to integrate the Public Interface with the everyday working environment of the end-user (e.g. virtual learning environments and other network applications) so that it will become a natural element of the work environment. The user will not need to use the native user interfaces of current IR-services since everything will be available via the Public Interface.

6.2 Authentication

There are three levels of user identification in the Public Interface: anonymous use without requiring the user to log in, weak identity (e.g. OpenID) and strong identity authentication service that can verify the end-user's identity.

The current and future national authentication and authorisation infrastructures will be used: HAKA national authentication federation at higher education institutions (HAKA, 2010), VIRTU for authenticating public administration officials (VIRTU, 2008) and VETUMA for authentication and payment system for citizens (VETUMA, 2008).

7. SERVICES OF THE PUBLIC INTERFACE

7.1 Multiple services in one interface

The Public Interface will provide direct access to multiple services that have traditionally been accessed through separate user interfaces in different organisations. In libraries, these services include the renewal of loans and holds, and fee handling. In museums, the corresponding functions could be the electronic purchase of a permission to use a copyright photograph. As for archives, the end-user could, for example, submit an electronic request to gain access to restricted archive material. With one login and single authentication throughout the Public Interface the end-user will have access to several accounts and services in different organisations.

Search functions will be the framework of the Public Interface into which other services will be integrated. A simple Google-type search (free text search) provides an easy way for the end-user to get started. Advanced search functionality will also be provided. For instance customers are able to limit the search by collection, archive and organisation, focusing the search on the selected targets. Queries can be refined by subject or time period, allowing the user to sort the query results and find the relevant documents from the massive amounts of data. Visualisation tools, such as term lists, tag clouds and hierarchy browser will be available for easy browsing of search results.

Depending on the material, the end-user will be provided with various navigation paths from reference data to full texts, images, videos, availability data of physical materials (e.g. books), etc. The search results can be enriched with data retrieved from external sources, such as book cover images or tables of contents. The end-user may see a thumbnail image, and having seen it he may decide to order a high-quality digitised image from the holding organisation. The Public Interface will connect the right kind of back-end service to a resource depending on the reference retrieved. The only requirement is that the service already exists in the back-end system and there is an API to connect the service to the Public interface.

These services are usually produced in the back-end systems. The aim is to integrate these services so that the end-user gets them through the Public Interface, but the actual technical implementation, upkeep and development of the service remains in the back-end systems (service through APIs). Ideally the customers should not even realise when they are using front-end services or back-end services – the customers only see the public interface.

7.2 User participation and social media

End-users will be able to participate in content production by enriching the metadata in the Public Interface by adding comments, reviews and tags to a record. Such social metadata will be stored in the Public Interface and can be used to support the retrieval functionality and selection and recommendations of references. The end-users will also be able to provide the participating organisations with additional information and feedback on organisations' cataloguing data concerning possible defects or errors in the metadata. This social data production will provide continuous improvement to the reliability and value of the metadata, and it can also be exported from the Public Interface to other systems. Additionally, we plan to utilise existing social media services, such as Facebook and other successful web services, by connecting these to the Public Interface via APIs.

8. CONCLUSIONS

8.1 Co-operation towards better services

The National Digital Library is an exceptional nationwide project and first of its kind in Finland since it is a co-operative undertaking and will provide the combined services and collections of the Finnish museums, archives and libraries for everyone through one versatile user interface. The Public Interface will be a comprehensive and user friendly IR tool which will substantially reduce the overlapping work and the costs of user interface development by cross-sectoral co-operation. During the development all three sectors have embraced co-operation and worked together to provide users a comprehensive new service to answer their information needs.

Understanding the end user needs and expectations has played a major role during the design process. Current portals are usually lacking in usability. Thus, our aim is to enhance the accessibility of resources through high usability. High usability will be achieved through rigorous usability testing and adapting tested user interface solutions which enable easy and fast information retrieval despite the large number of diverse users and high volume of heterogeneous content. Using the Public interface service will be effortless since it can be localised and customised to suit the varying needs of heterogeneous user groups while still managing to provide access to large amounts of versatile and diverse content. Available views of the user interface can be tailored to provide desired services, resources and automatic functionality for handling and analysing the search results and utilising already existing related services. The aspect of social media has also been taken into account by providing the users the possibility of participating by interacting with the content and even improving it by adding social metadata.

Accessibility and high usability improve information retrieval and the use of personal working environment of researchers, students and the general public and will increase the access and visibility of online cultural heritage materials.

8.2 Future Visions

The focus of this project is initially on the traditional text information retrieval of resources. In the future we envision the development of additional IR functionality to the Public interface, such as CLIR (Cross Lingual Information Retrieval) between Finnish, Swedish and English (Hedlund & al., 2000), CBMR (Content Based Music Retrieval) utilising the Finnish C-BRAHMS project (CBRAMS, 2010) and enhancing the content by adding geographical location data and further semantic web ontology functionality developed in the FinnONTO project (Hyvönen & al., 2008) : future services that answer the ever-changing customer needs even better.

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LONG-TERM ACCESS TO CULTURAL HERITAGE CONTENT IN FLANDERS: TOWARDS SUSTAINABLE VALORISATION

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KEY WORDS: Cultural Heritage, Digital Archives, Sustainability, Digitisation Life Cycle, Valorisation, Business Modelling

ABSTRACT:

This paper reports on early-stage research that aims at developing sustainable valorisation models for access to (and reuse of) digital cultural heritage content in Flanders (Belgium), particularly for use in education, research and the cultural sector and industries. The research is taking place within the ongoing large-scale collaborative research project Archipel. As this is work in progress, this paper will mainly focus on contextual and methodological concerns. Firstly, previous research has shown that digitisation progress is still limited in Flanders and that the road towards digital sustainability in all its facets remains long. Secondly, (policy) discussions on the (un)desirability of charging for cultural heritage content are addressed, as they are paramount in developing acceptable valorisation opportunities. After sketching these contextual factors, a methodological overview of business modelling approaches for developing valorisation models for cultural content distribution is given. In this approach, the value network with its actors and roles is sketched, as well as the financial model, functional architecture and value proposition for users. Some concerns on the applicability of the approach in this context are voiced. A final section highlights the main contextual and methodological considerations and, as the research is ongoing, concludes by outlining planned subsequent research steps. These include the development of possible scenarios for target group specific valorisation and their evaluation by means of participatory methods, involving stakeholders from the field.

1. INTRODUCTION

Sustainable digital access to cultural heritage has become an important policy goal throughout Europe and beyond (see e.g. Commission of the European Communities, 2008; The Council of the European Union, 2006; UNESCO, 2003). Attention for digitisation and digital preservation has continued to grow during the past years, whereby preservation is not merely seen as an end in itself (Edmondson, 2004), but is inextricably linked to the goal of making cultural (heritage) content more widely available. This field has not only been the subject of policy agendas, it is also an area of attention for collaborative cross-border research and development projects and networks, within Europe most notably Europeana and its related projects (Europeana, n.d.), and correspondingly also for individual institutions' remits and future agendas.

In this paper, we wish to focus on how the issues of digitisation, digital preservation and long-term accessibility are being tackled in the region of Flanders (Belgium). More specifically, we report on early-stage research currently conducted in Flanders, in which sustainable valorisation models for access to (and reuse of) digital cultural content for education, research purposes and the cultural sector and industries are sought. As this is work in progress, this paper will mainly focus on contextual and methodological concerns. The research is being carried out within the framework of an ongoing large-scale collaborative research project Archipel*. The project's aim is to map challenges posed by sustainable digital archiving in Flanders as they affect cultural, educational and scientific sectors. By applying a test bed approach, potential solutions are evaluated in order to contribute to the know-how needed to develop a sustainable digital archiving infrastructure. Archipel hereby focuses on a networked rather than centralised approach, and includes sustainable access and reuse in its scope as well as preservation. Alongside technological issues, organisational aspects are also researched. The analysis of valorisation opportunities for sustainable distribution and access forms an important part of the organisational and financial challenges.

A first section of the paper will elaborate on the context in which the sustainable valorisation models under development would be applied: we will look at past research to sketch the state of digitisation of cultural content in Flanders in all its aspects, mapping the progress made as well as some important remaining obstacles. The next section will focus more directly on the issue of developing sustainable valorisation models, starting with a literature and policy review of discussions on the (un)desirability of monetary valorisation of cultural (heritage) content. Subsequently, a methodological overview of business modelling approaches and their applicability – or lack thereof – for developing valorisation models for cultural content distribution will be given. A final section will focus on preliminary recommendations and areas of attention and, as the research is ongoing, will conclude with an outline of planned subsequent research steps.

2. DIGITISATION AND DIGITAL SUSTAINABILITY IN FLANDERS

2.1 Digitisation and sustainability: a conceptual overview

In order to understand the progress that has been made in the field of digitisation of cultural heritage and the sustainability aspects thereof, it is necessary to firstly demarcate the central concepts. *Digitisation* can cover a myriad of meanings, even when related to the scope of cultural (heritage) content. This conceptual ambivalence needs to be kept in mind throughout this paper. In a narrow sense, digitisation of content equals the conversion from analogue to digital formats, e.g. scanning a photograph. This is of course essential in digitally providing cultural heritage content that has not originated in digital form. However, digitisation can also be seen as encompassing far

* For more information on Archipel, we refer to Appendix A.

more than this one-dimensional process. This has been recognised in digitisation life cycle approaches. The Digital Curation Centre has undertaken thorough development of such approaches (see e.g. Higgins, 2008). Aside from digitisation in a narrow sense, life cycles e.g. also include digitisation preparation, digital preservation and publication in the essential tasks (see e.g. Minerva Working Group 6, 2004). The life cycle can differ to some extent in every project (Fernie, De Francesco & Dawson, 2008), but for our purposes we follow the view that it can be divided into four essential phases: the pre-digitisation phase or phase of content selection, the actual (narrow sense) digitisation phase, and two post-digitisation phases, one centred on internal data management and preservation, another on distribution and access (Moons, Van Passel & Nulens, 2009). In light of valorisation and funding issues, the distinction between both post-digitisation phases is critical.

Digital preservation is not only a step in digitisation life cycles; it has been outlined as an issue in its own right (Rothenberg, 1999; Hedstrom, 1998) and has since become a prevalent term to cover projects, programmes and literature focusing on longevity of digital information (see e.g. Santone & Straw, 2009; Sierman, 2009). The concept of *digital sustainability* appears to be less commonly used. Bradley (2007, p. 151) argues for a more widespread use of this term and defines it "*as encompassing the wide range of issues and concerns that contribute to the longevity of digital information*". He sees digital preservation as an integral part, with sustainability providing its context (Bradley, 2007, p. 151). Digital sustainability is understood to take organisational, economic, social, structural and technical questions into account and is closely linked to the aforementioned life cycle approaches. Adhering to these definitions, the research outlined in this paper would correspond more closely with the sustainability approach than with the more narrow preservation approach. Regardless of the term being used, it is clear that processes of active involvement are required to ensure the longevity of digital information. This is also implied in the related concepts of digital curation and digital stewardship Bradley (2007, pp. 161-162) additionally refers to. Digital stewardship (Anderson, Gallinger & Potter, 2009; Zorich, 2007; Farb, 2006) and digital curation (Higgins, 2008; Beagrie, 2006; Beagrie & Pothen, 2001) might differ from their analogue counterparts, but continue to assume responsibility, trustworthiness and qualitative engagement. In this paper, sustainability will be used as the overarching term; *sustainable digitisation* will refer to the whole life cycle with all its aspects.

2.2 Digitisation in a narrow sense: progress and obstacles

One indicator of the growing awareness of the need for sustainable digitisation of cultural heritage in Europe and Flanders is the research effort put into establishing the progress made. Digitisation in the narrow sense is an important indicator for sustainable digitisation; simply put, a certain amount of digital content is required for digital access. On a European level, the NUMERIC project aimed to measure the digitisation progress of cultural institutions' heritage content (NUMERIC, 2009). It has also been implemented in Belgium, but in spite of thorough research efforts, it remains highly difficult to obtain data on digitisation progress. The NUMERIC report for Flanders indicates that results have to be interpreted with caution because of relatively low response rates; the majority of institutions find it far from evident to produce sound data when it comes to their digitisation progress (Walterus, 2009, p. 22). Examples of resulting data – to be interpreted cautiously – include a digitisation rate of 0.84% for printed materials, 10.47% for audiovisual materials and 17.70% for image materials (Walterus, 2009, pp. 24-25). While the global digitisation status in Flanders appears to be similar to EU averages, a more direct comparison with the Netherlands shows that Flanders seems to lag behind (Walterus, 2009, pp. 25-29). Moreover, research shows that many Flemish institutions are insufficiently aware of the scale of their analogue holdings because of incomplete cataloguing: this was a key finding of in-depth interviews organised in the framework of Archipel's predecessor BOM-VL (Nulens & Debuysere, 2008, pp. 23-24). This is a contributing factor to the difficulty of estimating the digitisation progress: without knowing the total size of analogue collections, estimating the proportion of digitised items is impossible. To conclude, attempts at mapping the digitisation progress have underlined numerous obstacles that remain: lack of cataloguing of analogue data, insufficient descriptions and metadata, uncertainty about standardisation and formats, intellectual property rights, etc. Another impeding factor is the lack of long-term vision and planning, which leads us to look at digitisation in a more encompassing and sustainable sense.

2.3 Towards a long term approach: digital sustainability

As stated, working towards digital sustainability implies a life cycle approach, which involves many contributing factors. While technical factors are under considerable research within Archipel, they do not fall within the scope of this paper. Instead we wish to highlight the critical economic and organisational matter of sustainable valorisation and funding. While NUMERIC and BOM-VL did not directly include sustainability in their scope, the findings can nonetheless be seen as disconcerting to a certain extent when looking at the progress made towards digital sustainability in Flanders. No more than 36% of institutions had established a digitisation plan and only 21% had involved long-term archiving in its scope (Walterus, 2009, p. 21). The lack of planning has to be seen as a critical factor (Nulens & Debuysere, 2008, p. 25). It can be expected to correspond with a lack of dedicated funds, as institutions that do not have a detailed plan might not have allocated specific budgets for digitisation, let alone digital sustainability. This can threaten the longevity and accessibility of the digital data resulting from any efforts made. An interesting way to address this could be found in the Netherlands: a dedicated subsidising mechanism was established to encourage the development of digitisation plans. For 2009, the Ministry of Education, Culture and Science foresaw a budget of 700,000 euro in digitisation planning funds. It has been suggested that a similar funding scheme could prove useful in Flanders (Moons, Van Passel & Nulens, 2009, p. 55). However, the Dutch funding mechanism is no longer available in 2010 (SenterNovem, 2010). In the context of digital sustainability, this can be deemed regrettable.

Scientific research into financing opportunities and models for sustainable digitisation of cultural heritage in Flanders has shown that assuring continuous funding for digital sustainability is far from straightforward (Moons, Van Passel & Nulens, 2009). The study looked into the opportunities and limitations of various forms of direct and indirect public funding, private support and mixed (public-private) financing. First, a broader overview of potential financing models was given, based on an extensive literature study and European digitisation case studies. The specific Flemish context with its financing traditions, also mapped through desk research, was then used to evaluate the feasibility of the financing models. A concluding expert panel discussion was conducted to evaluate the findings. In the conclusions of the study, an integrated financing approach was brought forward, indicating that sustainable financing implies a mix of funding sources, but nonetheless stressing the continuous importance of subsidies and the limited applicability of revenue models related to charging for content. Viable financing models for each life cycle phase were listed and content-related revenue models were only deemed feasible to (partially) fund the phase of distribution and access, and even then revenue perspectives remain small and content should remain at least partially free to access (Moons, Van Passel & Nulens, pp. 83-92).* Indeed, discussions on desirability of charging for access, as will be outlined in the next section, only complicate the matter. In sum, cultural heritage content is not easily monetised, and public funds will remain essential in achieving digital sustainability.

2.4 Sustainability of access in a European perspective

In light of wide-ranging access, it must be stressed that cultural heritage content originating from Flemish institutions can reach far beyond regional borders. This breaking of boundaries, utopian as it may seem, can be seen as one of the digital age's main benefits. While this is not the main scope of this paper, it is critical to take into account upon developing valorisation models. We cannot deny that the specificity of the Flemish context is important within Archipel; target groups under consideration for valorisation models include education, research and cultural sectors and industries in Flanders. Moreover, while sustainability of digital collections has been the subject of attention of many earlier studies, many including funding and valorisation in their scope (Lavoie, 2004; Zorich, 2003; National Initiative for a Networked Cultural Heritage, 2002, to name but a few) the study of financing traditions (Moons, Van Passel & Nulens, 2009) has shown that there are still regionally specific factors that need to be taken into account upon developing valorisation models. Nonetheless, it can be argued that Flanders should not be a digital island; Archipel as a whole is certainly learning a lot from earlier research outside of Flanders. Research has indicated that Flemish institutions themselves find it important to reach beyond regional boundaries and wish to be involved in cross-border (European) projects (Nulens & Debuysere, 2008, p. 30). Moreover, existing external websites, content portals and communities are seen to have potential value in reaching certain audiences with cultural content (Van Passel & Beyl, 2008). Technologically, Archipel takes this into account in its test bed approach, e.g. by foreseeing links to the Europeana portal. From a valorisation perspective, increased visibility for content as well as institutions can be beneficial.

3. TOWARDS SUSTAINABLE VALORISATION FOR LONG TERM ACCESSIBILITY

3.1 Valorisation of cultural content: underlying issues

In recent policy documents and discussions, positions on access for everyone and the safeguarding of public domain content have been outlined, on the European level particularly in relation to the large-scale cross-border portal Europeana (European Parliament, 2010; The Council of the European Union, 2010; Commission of the European Communities, 2009). One important view is that *"(...) public domain content in the analogue world should remain in the public domain in the digital environment even after the format shift"* (European Parliament, 2010, p. 7). In Flanders, the Ministry of Culture has also adopted this stance (Schauvliege, 2010). Europeana has recently published its own Public Domain Charter highlighting the importance of the online public domain (Europeana, 2010). Policy views of this nature reflect an ongoing debate and controversy in the area of content digitisation when access to this content is considered to be of public value. The debate is linked to theories on cultural versus economic value (Holden, 2004; Throsby, 2001) and has been especially heated when private partners acquire (partial) content ownership within public-private digitisation partnerships, the Google Books project being a notable example (Pike, 2009). Intellectual property rights are a critical factor in this discussion, as they are not always easily reconciled with a call for wide-ranging access for public value. While copyright issues and related legal aspects do not fall within the scope of this paper, many cultural institutions regard them as a hindrance to digitisation (de Haan et al., 2006). Copyright aspects inevitably have an impact on the feasibility and applicability of potential monetary valorisation scenarios.

The importance that is being ascribed to the role initiatives such as Europeana can play in making more content available in the public domain indicates that digital access to cultural heritage is increasingly being recognised as having value in itself. This can be contrasted with the suggestion that earlier cultural (institutions') websites could often mainly be seen as mere marketing tools for their offline counterparts, as described in earlier research in Flanders (Pauwels, Van Oost & Lavens, 2004). Limited amounts of available content have been deemed to at least partially explain a lack of virtual cultural participation (Nulens, 2009). Without going deeper into the cultural and economic value discussion, if increased digital accessibility is seen as a potential means to increase the level of valuable virtual participation, we can wonder if charging for access will limit these participation levels. While accessibility does not necessarily imply that access is completely free of charge (Consortium Beelden voor de Toekomst, 2006), in the cultural heritage realm, the importance of removing as many barriers to access as possible is not often denied.

As such, developing monetary valorisation models for cultural heritage content is not straightforward and can even be seen as controversial. A search for financing and valorisation models cannot lose track of cultural heritage's public value and the resulting need for access; this has been acknowledged in former research (Moons, Van Passel & Nulens, 2009) and remains highly important within Archipel. This is related to the required target group specificity of valorisation models: when end users or citizens access cultural content online, this might conjure up different associations in the aforementioned discussions than when private entities access content for commercial purposes. In light of this research, it is important to stress that valorisation aspects are by no means limited to economic or monetary valorisation; the focus on public and societal value within the access discourse should demonstrate this sufficiently. Nonetheless, in light of organisational feasibility and sustainability of funding, economic valorisation remains a critical factor. To enable a better understanding of the issues at hand, the methodological approach of business modelling will be outlined and contextually evaluated in the next section.

3.2 Business modelling approaches to valorisation

In the outset of Archipel, business modelling was selected as a methodological approach towards devising sustainable valorisation scenarios, as achieving economic sustainability is highly important. However, as the previous section has ascertained, economic valorisation propositions are not as straightforward in the cultural heritage realm as they might be in other sectors. Nonetheless, business modelling has been gaining interest in the domain. In The Netherlands for example, the business modelling canvas of Osterwalder and Pigneur (2009)

* For a more detailed schematic overview of these conclusions, we refer to Appendix B.

has recently been utilised to highlight the importance of business model innovation in the cultural heritage sector (Verwayen & Limonard, 2009). This canvas is made up of 9 building blocks: customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partnerships and cost structure (Osterwalder & Pigneur, 2009). It has been applied to map differences between analogue and digital business models for archives: e.g. digital distribution creates new essential partnerships (with distribution partners such as Flickr.com), new customer relationships (from a distance rather than on-site), etc. (Verwayen & Limonard, 2009, pp. 19-21).

The specific method we will use has been outlined and refined in the context of ICT (see e.g. Ballon, 2009; Ballon, 2007; Faber et al., 2003). In this approach, the *value network* with its actors and roles is sketched, as well as the *financial model*, *functional architecture* and *value proposition* for users. In contrast with the example of analogue and digital business models for archives outlined above, the approach we will apply centres more on the network than on its individual actors. This explains its particular applicability in light of the Archipel project, which is equally network-centric in its outset. The parameters of value and control that are central in this method (Ballon, 2009; Ballon, 2007) are also relevant in the context of digital cultural heritage; it can be applied regardless of the possible non-profit ("non-business") nature of actors involved. From a business perspective, it can even be said that cultural goods have a very similar value chain to e.g. software (Braet, 2009). However, important questions remain when it comes to the limits of the applicability of business modelling approaches in this context. The previous section has certainly shown that there is more at stake than can be covered by a business perspective. In light of public domain and free access, the value proposition, i.e. low-barrier access to cultural content, does not necessarily correspond with a financial gain for institutions providing the access.

Nonetheless, the selected business modelling method can help to map and understand changes cultural heritage stakeholders are facing while working towards long-term digital availability of content. A more modelled approach can be useful to map the impact of some of the aforementioned contextual factors. For example, the *value network* relevant to sustainable access is likely to be highly complicated, with many actors and partners involved. Understanding which roles and responsibilities certain partners will have to take on is paramount in achieving digital sustainability. The *functional architecture* of sustainable valorisation scenarios will need to take the different digitisation life cycle phases into account, while the *financial model* for digital sustainability is also linked to the life cycle and will need to include public funding, as the services proposed are in the public value realm. As far as the *value proposition* is concerned, we have indicated that a target group specific approach will be required, e.g. by highlighting that the question whether or not charging for content is desirable might be answered differently in an educational than in a (culturally) commercial context. The valorisation scenarios will have to keep these different potential outcomes for different target groups in mind. In sum, as long as the limitations of business modelling within the specific context are recognised, the methodology can certainly be utilised.

4. DISCUSSION: SUBSEQUENT RESEARCH STEPS

In this paper, we have reported on the early stages of research that is being conducted in Flanders in order to develop sustainable valorisation models for the distribution and potential reuse of cultural heritage content. As the research is ongoing, we have focused on the main contextual and methodological factors that will have to be kept in mind. Firstly, looking at literature and previous research, we have outlined contextual factors that influence the applicability of potential valorisation scenarios. These include the status of digitisation in Flanders and the attention given to sustainability in this field: previous research has highlighted that the road towards digital sustainability in all its facets remains long. The controversy surrounding public value and the public domain versus content-based revenue models online is another important contextual factor. Secondly, we have focused on methodological questions that arise upon developing valorisation models and we have elaborated on business modelling approaches as a possible answer. Keeping the contextual factors in mind, we have outlined how these approaches can be applied in the realm of online cultural content distribution, acknowledging their possible constraints.

The next research steps will build on the selected business modelling approach to map the value network and concretely develop possible valorisation scenarios. Separate models for cultural content distribution towards (1) education, (2) research purposes and (3) cultural sectors and industries will be devised. These will then be evaluated by means of participatory methods, involving stakeholders from the concerned sectors. Because of the high complexity of the issues at hand, expert panel discussions (Slocum, 2003, p. 87) are deemed the most appropriate evaluation method. Separate panel discussions for the three main valorisation target groups will be organised and analysed. This paper intends to provide a useful background to the subsequent research steps: throughout the remainder of the research, the contextual factors and methodological constraints that we have outlined will continuously have to be kept in mind.

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APPENDIX A. ARCHIPEL PROJECT INFORMATION

"Archipel, network-centric approach to sustainable digital archives" - http://www.archipel-project.be/
Funding: IWT (Agency for Innovation by Science and Technology), PIM framework (Programme Innovative Media) - http://www.iwt.be/
Project Partners: BAM (Institute for Visual, Audiovisual and Media Art); Boekentoren (University of Ghent – University Library); FARO (Flemish Institute for Cultural Heritage); Klascement (Portal site from / for the educational sector); VTi (Flemish Theatre Institute); Inuits; Krimson; Porthus; IBBT-ICRI (Katholieke Universiteit Leuven); IBBT-MICT (Universiteit Gent); IBBT-MMLAB (Universiteit Gent); IBBT-SMIT (Vrije Universiteit Brussel)

APPENDIX B. THE DIGITISATION LIFE CYCLE

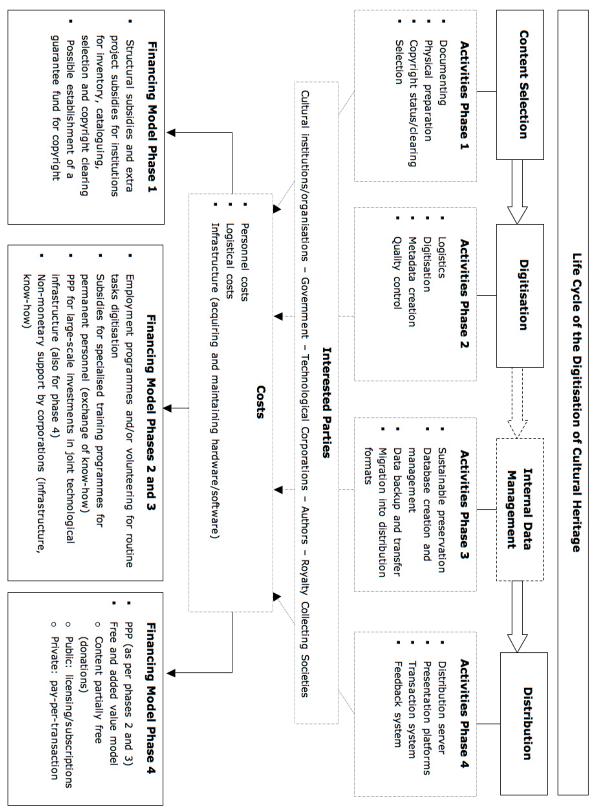

Figure 1: Life cycle of the Digitisation of Cultural Heritage (Moons, Van Passel & Nulens, 2009, p. 86; authors' own translation)

DIGITAL LIBRARY FOR BULGARIAN TRADITIONAL CULTURE AND FOLKLORE

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KEY WORDS: Bulgarian Folklore, Multimedia Digital Libraries, Functionality, Services

ABSTRACT:

The Bulgarian folklore digital library is built during the "Development of Digital Libraries and Information Portal with Virtual Exposition 'Bulgarian Folklore Heritage'" module of the national research project "Knowledge Technologies for Creation of Digital Presentation and Significant Repositories of Folklore Heritage". This Internet-based environment is a place where folklore objects (mainly from the Funds of the Institute for Folklore at the Bulgarian Academy of Sciences) of different kinds and origins were documented, classified, and „exhibited" in order to be widely accessible to both professional researchers and the wide audience. This paper describes the library, its main services and components, their implementation and testing procedures. The paper also discusses problems arising during the formalization of folklore knowledge and the Bulgarian folklore ontology development, needed for semantic annotation of folklore objects in the library.

1. INTRODUCTION

Preserving and presenting the national folklore heritage is a long-term commitment of scholars and researchers working in many areas. From centuries every generation aims to keep records about work and social life, so that they could be revised and studied by the next generations. For a long time this heritage has been maintained in libraries, museums and research laboratories, where not everyone was able to access this wealth.

New information and multimedia technologies that have been developed during the past couple of years introduced new methods of documentation, maintenance and distribution of the huge amounts of collected material. Among these new technologies are digital libraries, which have already proven their worth as a contemporary conceptual solution for access to information archives. Digital libraries contain diverse hypertext-organized collections of information (digital objects such as text, images, and media objects) that are organized thematically and are managed by complex specialized services such as content structuring, advanced search (semantic-based search, multilayer and personalized search, context-based search), resources and collection management, information retrieval, indexing, semantic annotation of digital resources and collections, content grouping, metadata management, personalization and adaptive access, multilinguality, digital information protection and preservation, tracking services, etc. (Pavlov et al., 2006). Digital libraries enable "any citizen to access all human knowledge any time and anywhere, in a friendly, multi-modal, efficient, and affective way, by overcoming barriers of distance, language, and culture and by using multiple Internet-connected devices" (Brainstorming report, 2001).

In an attempt to answer the need of wider accessibility and popularization of Bulgarian folklore culture, a team from the Institute of Mathematics and Informatics has developed a Bulgarian folklore digital library (BFDL) within the "Knowledge Technologies for Creation of Digital Presentation and Significant Repositories of Folklore Heritage" national research project (Folknow). The project aims to develop a complete web-based environment for a virtual presentation of the Bulgarian folklore treasure kept in the funds of the Institute for Folklore of the Bulgarian Academy of Sciences.

This paper presents the Folknow project, its vision and ideas. The functional specification, implementation and testing of the Bulgarian folklore digital library are described, extending the presentation made in (Rangochev et al., 2007). The paper also discusses problems arising during the formalization of folklore knowledge and the Bulgarian folklore ontology development, needed for semantic annotation of folklore objects in the library.

2. FOLKNOW PROJECT

The project "Knowledge Technologies for Creation of Digital Presentation and Significant Repositories of Folklore Heritage" started 4 years ago with fundamental research on contemporary technologies for virtual exposition of intangible cultural heritage. Its aim is to build an experimental release multimedia digital library for the registration, documentation, and access to a wide range of Bulgarian folklore objects. The complex structure and the multi-layer characters of the folklore objects require an innovative approach for knowledge representation. The rich-in-content web-presenting of the Bulgarian folklore knowledge defines the usage of modern methods and technologies for developing a digital archive, which will be used not only for preservation and access to the information, but as a tool for scientific research analysis development. The main project's tasks are to create a digital library and information artery with semantic-sensible inferring maintenance in order to present in virtual form the valuable phenomena of the Bulgarian folklore heritage in a comprehensive and easy-to-use way. The realization of the project gives a possibility for wide social applications of the multimedia collections for the purposes of interactive distance learning/self-learning, research activities in the field of Bulgarian traditional culture, and for cultural tourism and ethnotourism in Bulgaria.

3. COMPLEXITY OF THE BULGARIAN FOLKLORE DOMAIN

The folklore knowledge and therefore the ethnological research have a systemic character (Rangochev, 1997). Since the early period of Bulgarian ethnology until the present day, scholars describe, investigate, and analyse different descriptive schemas for this knowledge. As a rule, scholars study a certain area of knowledge in a particular topos of the Bulgarian ethnical territory and find out an algorithm (where there is a process) or a structural description and afterwards the procedure is repeated in another topos, etc. Finally, a summarized algorithm or a structural description is achieved which is – as a matter of fact – the research abstraction (for instance, the “full” description of the “Bulgarian koleduvane” (Christmas rites) is an algorithm which does not coincide with its local variants). All this means that the ethnological studies are hierarchically organized. Leaving the particular topos (a village, for instance), the scholar focuses on bigger entities (such as a region, ethnographical region, or an ethnical territory) and thus he deals with a model of the studied area of ethnological knowledge. A danger in this hierarchical modelling could be the possibility to neglect important systematic links of knowledge (For instance, if we consider some folklore paradigms of kinship, it can turn out that the same person is involved in several systems of kinship: 1. by blood: grandson- son-brother-uncle; 2. by rite: brother-in-law; 3. by profession).

Another problem comes from the specifics of fieldwork investigations. As a rule, the scholar extracts parts of the ethnological knowledge by the means of interview with the informants. Therefore, ethnologists study phenomena which are not person-specific but characterize the community but they use for this purpose the memories and opinions of particular people.

Another important problem is the specifics of the ethnological research: these types of studies are mostly abstract, due to several historical, objective and subjective reasons (technology of recording, ethical, ideological, and scholarly prejudices, etc.). The records of samples of Bulgarian folklore which are studied by scholars in practice contain partial information: for instance, songs have been recorded only as texts without notation; or there is no information for the discourse practices conveying the oral narratives; or in many cases the records are made by means of structured interviews and not by inclusive interviews. Therefore, the conclusions of scholars are usually based on partial information (Rangochev, 1997).

All these problems require new flexible methods for representation of knowledge in formal and single structures for securing manners of access and management of this knowledge. In order to formally represent the folklore knowledge the ontology of the Bulgarian folklore was produced.

4. ONTOLOGICAL PRESENTATION OF THE FOLKLORE KNOWLEDGE

Originally, the term ontology comes from philosophy where it is employed to describe the existence of beings in the world. In 1993, Gruber’s definition becomes the most referenced on the knowledge technologies literature: “ontology is a formal, explicit specification of a shared conceptualization”. Conceptualization refers to an abstract model of phenomena in the world by having identified the relevant concepts of those phenomena. Explicit means that the type of concepts used and the constraints on their use are explicitly defined. Formal refers to the fact that the ontology should be machine readable, which excludes natural language. Shared reflects the notion that an ontology captures consensual knowledge, that is, it is not private to some individual, but accepted by a group.

Ontologies can be used for many different purposes. The literature on knowledge representation contains research on the use of ontologies for data-interchange, for data-integration, for data-querying or for data visualization. In general, visualization of information can be seen as a two-step process. In a first step, information is transformed into some intermediate semantic structure. This structure organizes the raw information into a meaningful structure. In a second step, this semantic structure is used as the basis for a formal visual representation. We used this approach in our work on the Bulgarian folklore ontology development.

To efficiently represent the folklore annotation framework and to integrate all the existing data representations into a standardized data specification, the folklore ontology need to be represented in a format (language) that not enforce semantic constraints on folklore data, but can also facilitate reasoning tasks on folklore data using semantic query algebra. This motivates the representation of Bulgarian folklore ontological model in Web Ontology Language (OWL). OWL facilitates greater machine interpretability of Web content than that supported by XML, RDF, and RDF Schema by providing additional vocabulary along with a formal semantics. Knowledge captured from folklore data using OWL is classified in a rich hierarchy of concepts and their inter-relationships. OWL is compositional and dynamic, relying on notions of classification, reasoning, consistency, retrieval and querying. We investigated the use of OWL for making Bulgarian folklore ontology using Protégé OWL Plug-in.

4.1 Ontology of the Bulgarian Folklore

Since one of the targets of the Folknow project is to present the valuable phenomena of the Bulgarian folklore in suitable virtual form using knowledge technologies, we have to observe and specify the experience that has been gained in the last 500 years in the area of traditional folklore i.e. to construct Bulgarian folklore domain ontology.

FolkKnow annotator/indexers using this ontology will semantically describe and index the raw audiovisual content in order to create and maintain reusable digital objects for the BFDL.

The ontology will be also used to realize semantic-based access to concrete digital objects, representing folklore objects, described by their main features, technical data or context. All this information is included within the Folklore Ontology Concept – the root concept for the ontology.

The process of building of the Bulgarian folklore ontology for the Folknow project is necessarily iterative. The first activity is the definition of the scope of the ontology. Scoping has been mainly based on several brainstorming sessions with folklorists and content providers. Having these brainstorming sessions allowed the production of most of the potentially relevant terms. At this stage, the terms alone represented the concept, thus concealing significant ambiguities and differences of opinion.
A clear issue that arose during these sessions was the difficulty in discovering of definite number of concepts and relations

between these concepts. The concepts listed during the brainstorming sessions were grouped in areas of work corresponding naturally arising sub-groups. Most of the important concepts and many terms were identified. The main work of building the ontology was then to produce accurate definitions.

The folklore object is related to two levels of knowledge, enriched with a set of sub-levels of the data classification. All these levels of knowledge or "thematic entities" in the ontology conception are supported by the scientific diagnosis results and the related documentation. The entity "Identification and description" consists of general historical data, identifying aspects such as title, language, archival signature, period, current location of the folklore object, annotation, first level description, second level description, etc. The entity "Technical" includes technical information both revealing the technologies used for folklore object capturing and recording, record situation, record type, record place, record date, main participants in the process (record maker and informant), etc. Figure 1 depicts part of the main concepts and properties in the Bulgarian folklore ontological model.

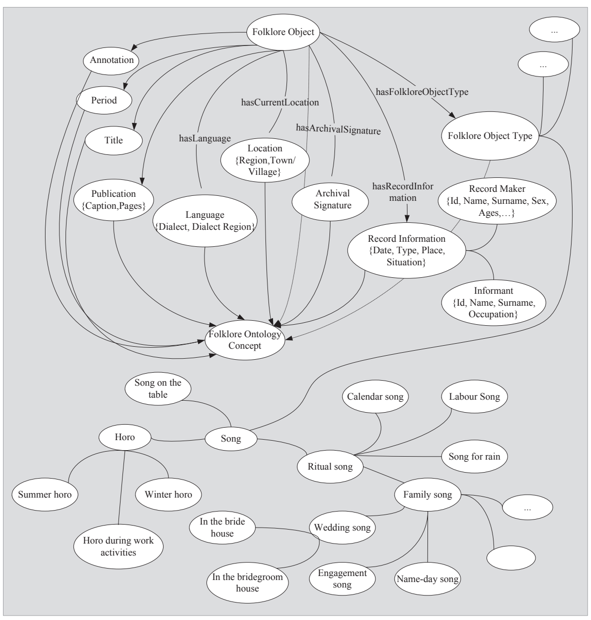

Figure 1: Part of the main concepts and properties in the ontology of the Bulgarian folklore

A detailed description of the ontology of the Bulgarian folklore is made in (Paneva et al., 2007; Luchev et al., 2008).

4.2 Semantics of a Complex Folklore Object

According to the classificatory categories in the Funds of the Institute of folklore of the Bulgarian Academy of Sciences the folklore objects are simple (for example, "song", "food", "magic", etc.) and complex (archived objects which cannot be so clearly and unanimously classified: the same units (parts), according to its informational content, could be classified into different Folklore Object Types).

Example of a complex folklore object is CFO A1_146_2-14, an interview containing information of the catholic community in the village of Oresh, Svishtov region, northern Bulgaria (see figure 2). The emphasis in the interview is on the ritual, festival, and everyday life in the village, on the popular beliefs and knowledge. Every one of these folklore object types has several sub-categories, depicted on figure 2.

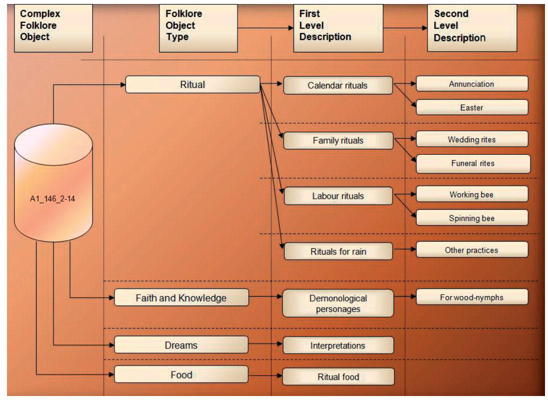

Figure 2: Example of a complex folklore object

The complex folklore object A1_146_2-14 annotated according to the ontology of the Bulgarian folklore has four subclasses of the Folklore_Object_Type class, in particular: "Ritual", "Faith and Knowledge", "Dreams" and "Food". They have also the following sub-subclasses: "Calendar Rituals", "Family Rituals", "Labour Rituals", and "Rituals for Rain" (Ritual class); "Demonological Personages" (Faith and Knowledge class); "Interpretations" (Dreams class); "Ritual" (Food class). On the next level, this complex folklore object is semantically represented by "Annunciation", "Easter", "Wedding rites", "Funeral rites", "Working Bee", "Spinning Bee", and "Other practices" in Ritual sub-subclass; further it is represented by "Wood-nymphs" in Faith and Knowledge sub-subclass, etc.

5. FUNCTIONAL SPECIFICATION OF THE BULGARIAN FOLKLORE DIGITAL LIBRARY

The key for the current release of BFDL is the efficiency and the provision of strictly designed functionalities, powered by a long-term observation of the users' preferences, cognitive goals, and needs, aiming to find an optimal functionality solution for the end users. In BFDL we also follow the requirements of experts in the area of Bulgarian folklore and the accepted functional specification for a digital library. Following them the basic BFDL functional modules are:

- A module for adding and editing folklore objects. The library expects as an input two types of objects: simple folklore objects and complex folklore objects.
- A module for viewing the content of folklore objects (according to their base type and rubric to which they belong or by different descriptive characteristics). Figure 3 shows a snapshot of a folklore object.
- A module for searching by: signature and archive number; keywords of the following categories: name, language, annotation, type of the folklore object/rubric; file type; record information (simultaneously or one by one): by situation, by reporter name, by recorder name, by record date and by recording location; extended search – it

provides the option for searching through all the object characteristics;

Figure 3: Folklore object preview

- A module for managing the user data;
- A module for monitoring the user's actions, which keeps track of the following: a) Actions related to working with the system: registration, logging in the system, unsuccessful log-in attempts, logging out, changing of the user password, e-mail address change, etc.; b) Actions related to the object manipulation: adding an object, editing an object, deleting an object, adding a file, deleting a file; c) Actions related to the content viewing: review of objects by their characteristics, view of a single object, searching for objects by characteristics; d) Other administrative actions: changing the user's level, deleting a user, generation of an XML copy of the data in the system;
- A module for file format conversion;
- A module for generation of XML copies of the objects in the system.

The module for viewing the content of folklore objects is available to all users of the library, except the administrators. The reason is that the administrators of such systems are often people who don't have any relation to their content; they only do support tasks. The module itself was implemented similar to the Windows OS file browser and KDE, so that it is closer to the familiar user interfaces for viewing hierarchical information. The left side shows a tree of all classes, which inherit "Type of folklore object", and the right side shows a list of objects of the selected class in the tree.

The module for creating and editing folklore objects is used for adding new objects and modifying the information of already created objects. Through it, one can add more multimedia files to an object or delete existing ones.

Searching for information is the most frequent search and therefore the most important operation in a digital library. This is why there are several modules for searching by different criteria:

- Searching by a signature or archive number – This search module is useful for finding objects by their archive number (for example, AIF No 200, folder 1, page 57). In general, there is only one search result. In case of incorrect data, it is possible to have several objects as a result.
- Search by a keyword in the object properties – by name, language, annotation and type of the folklore object – Searching is performed simultaneously over all these properties. It is expected that this module is the most frequently used one. This is why special attention has been paid to its optimization.
- Searching by record information – This module is used to find all the objects which cover some of the following conditions: all the objects recorded in a given situation, for example an interview, chat/conversation, etc.; all the objects recorded by a given person; all the objects recorded by a given informer; all the objects recorded in a given period of time; all the objects recorded in a given location.
- Searching by file type – This module allows getting a list of all the objects to which there is a multimedia file attached – audio, video or images. This type of searching uses the database in which the administrative information is stored instead of the OWL file that contains the ontology.
- Complex search on all fields semantically describing the folklore object. Using this search simple and complex folklore objects could be found, tracking their semantic metadata records.

Most types of searching use SPARQL (SPARQL Protocol and RDF Query Language). This is a language for requests to the RDF and OWL ontologies. The language is in a standardization process by RDF Data Access Working Group as an official recommendation of the World Wide Web Consortium. The SPARQL syntax is similar to the most widespread language for database requests – SQL.

The module for monitoring the user's actions is intended to keep logs of the objects modified and deleted by the users, so that in case of data deleted by mistake or entered wrongly, the responsible user can be found. There is also a log of search requests, whose purpose is to enable statistical reports about the search types that are used least and most often. It would allow the removal of the rarely used search types and the priority optimization of the ones that are used most often.

The module for file format conversion was developed to provide the ability to present every file which is unsuitable for internet preview in a "light" and convenient form for web preview. The module recognizes the "inconvenient" files, tries to covert them and on success replaces the original file with the new "lighter" file; on failure, the module keeps the original file in the library. The module for generating an XML copy of the data is available only to the system administrators. The purpose behind this module is creating a copy, which can be used as an archive copy on one hand and on the other hand it may serve as raw data for other systems using information from the library.

The presented BFDL functionality aims to serve a wide range of users – specialist and non-specialist. The group of specialists is composed by scientists who study Bulgarian folklore professionally and search for specialized information on the observed folklore objects. The group of non-specialists has interests and wants only to learn more about the classical Bulgarian folklore objects. The BFDL system supports several users' levels: administrators, folklore content editors, specialist viewers and non-specialists viewers. Their individual characteristics, needs, interests, motivation, and preferences are discussed in (Pavlov et al., 2006).

6. IMPLEMENTATION AND TESTING THE BULGARIAN FOLKLORE DIGITAL LIBRARY

A module for adding objects to the BFDL – Adding objects is implemented through filling and sending a form to the web server. Because of the great number of fields to fill, the form is not generated completely. Only the fields necessary for the creation of the objects are generated, following the semantic descriptions presented in the BFO, built at the first stage of module 3 of the project. The technology used for the implementation is AJAX. The user interface passes a request to the server, in which it requires only that part of the form which according to the user is necessary to create the object. The server processes the request and returns the required fields as a result, which is visualized in the user interface. After all the fields are filled, the user submits the form. The server validates the data and if everything is correct, it adds the object to the data storage. If there is something wrong, it returns a message to the user, relative with the error (usually, an empty field or unacceptable field value). After the server adds the information from the form to the data storage, there follows a check for attached files in the user request. If there are attached files, the server checks if there are file formats which are unsuitable for web presentation (for example, wav, .doc, .mpg, .avi, .mpeg, etc.) and if it finds such files, the system refers to the module for file format conversion to formats suitable for web preview. For each of these files, the module for file format conversion tries to convert them. Upon success, it adds the converted file to the library. On failure (which can occur if the added file has any specifics which the system cannot recognize), it adds the original file to the library. At the end of the object adding procedure, the system refers to the module for monitoring the user actions, where it adds an "object added" event and records the author (the user who created the object) and the event date.

A module for editing objects in a BFDL – The module for editing objects works almost in the same way as the module for adding objects. The difference is that the system doesn't add information about a new object, but replaces the existing information about an object with the new information, provided by the module for editing. Again, the system checks the form for errors, processes the files (if there are new files added), changes its data and finally adds an event for modified object through the module for monitoring the user's activity.

A module for viewing the content of folklore objects – This module takes a request from a user, in which the user specifies the property by which a folklore objects must be found. The module refers to the data storage and makes a request for selecting and sorting the objects by this property. The module for monitoring the users' actions records the "view objects by" event and adds data about the date, the user and the property by which objects are listed. The storage processes the request and returns a result, which the system processes and sends to the user. The user interface visualizes the result in a proper manner.

A module for searching – This module allows the user to set a property or properties by which objects are found. The following algorithms are used:

The algorithm for searching by a single property – The user interface sends a request to the data server specifying the property and its needed value. The module for searching refers to the data storage of semantic metadata with a query for selection and sorting the objects with the needed value of the specified property. The module for monitoring the user actions records the "search" event with the provided search parameters, the date and the user, who performs the search. The storage processes the request and returns a result, which is then processed by the search module and displayed in a proper manner by the user interface.

The algorithm for searching by more than a single property – The algorithm is parallel to the one described above, with the only difference that the query to the data storage is more complicated – there are multiple selections of objects for each search property and the result is a sorted section of the selection results.

After an analysis of the means and standards in the technological implementation of the library environment and the functional modules, the following software was chosen: Operating system: Microsoft Windows Server 2008 x64 Standard; Web server: Apache HTTP Server v 2.2, PHP v 2.2.9; Database management system: MySQL v 5.1 Standard; Tools for the additional modules: FFMPEG, vwWare, HTML, JavaScript, AJAX; Database query language: SPARQL.

The functional components of the architecture of the BFDL were implemented and tested for errors and speed on a server platform with the following hardware configuration: CPU: 2 x Intel QuadCore 2.8 GHz; RAM: 8GB DDR3; HDD: 4 x 500GB, RAID 10 SATA II; LAN: 2 x 1000Mbit.

Testing the functional module for adding/editing a folklore object – Server response time (average of 50 attempts): 0.0058 s, i.e. in theory the functional module for adding/editing an object can process about 172 requests per second for each processor core, which makes 172*8=1376 requests.

Testing the module for viewing folklore objects – Time for server response: 0.009 seconds per request, i.e. 888 requests per second.

Testing the module for searching by a single property – Time for server response: 0.008 seconds per query, i.e. 1000 requests per second.

Testing the module for searching by several properties – The test was performed with 25 properties (it will happen very rarely). Time for server response: 0.01 seconds per query, i.e. 800 requests per second.

Testing the module for file format conversion – Converting video files: the server sends a response before it converts the video file, because the process is relatively slow. The average time of processing a video file is about 30 seconds, i.e. you can add about 16 video objects per minute. In this way, after adding a video object, its actual recording in the BFDL happens in 30 seconds.

Converting audio files – The server responds before the file is actually processed. The average time for processing an audio file is about 10 seconds, i.e. in theory a system with such a configuration can process about 48 audio files per minute.

Converting MS Word (.doc) files – The conversion takes place in real time. The average server response time is 0.04 seconds per request, which are about 200 requests per second.

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ON THE WIDER ACCESSIBILITY OF THE VALUABLE PHENOMENA OF THE ORTHODOX ICONOGRAPHY THROUGH A DIGITAL LIBRARY

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KEY WORDS: East Christian Iconographical Art, Multimedia Digital Libraries, Services, Domain Ontologies

ABSTRACT:

Over the last years several initiatives were carried out worldwide towards on-line documentation, exposure, storage and preservation of cultural heritage. In this framework, many valuable masterpieces of Orthodox iconography have been digitalized and appeared in the virtual space. However, rare specimens, private collections, icons from difficult-to-access storages, distant churches, chapels, and monasteries, objects in a risk environment or unstable conditions were almost "untouchable" for the e-user. In an attempt to answer these needs of wider iconographical objects accessibility, a team from the Institute of Mathematics and Informatics has developed a multimedia digital library called *Virtual Encyclopaedia of Bulgarian Iconography*. This Internet-based environment becomes a place where East Christian iconographical objects of different kinds and origins were documented, classified, and „exhibited" in front of professional researchers and the public. This paper does a complete description of this digital library, passing from the semantic description of the iconographical art content to the library architecture and functionalities.

1. INTRODUCTION

Orthodox (East Christian) iconographical art is recognised as one of the most significant areas of the art of painting. Until recently, it is being neglected in the digital documentation and the registry of the art of painting. But the accessibility to that valuable part of mankind's cultural and historical ancestry was enhanced greatly with the appearance of the *"Virtual Encyclopaedia of the Bulgarian Iconography" multimedia digital library* (also called Bulgarian Iconography Digital Library, BIDL) in the world virtual space (http://mdl.cc.bas.bg/). This Internet-based environment becomes a place where iconographical objects of different kinds and origins were documented, classified, and „exhibited" in order to be widely accessible to both professional researchers and the wide audience. Rare specimens, private collections, icons from difficult-to-access storages, distant churches, chapels, and monasteries, objects in a risk environment or unstable conditions, etc. are appearing for new e-exposition. The library provides services for registration, documentation, access and exploration of a practically unlimited number of Orthodox iconographical artefacts and knowledge (Pavlova-Draganova et al., 2007a; Pavlov et al., 2006) and the end users could use this rich knowledge base through its interactive preview, objects complex search, selection, and group. The first release of the BIDL was developed five years ago during the national project *"Digital Libraries with Multimedia Content and its Application in Bulgarian Cultural Heritage"* (contract 8/21.07.2005 between the Institute of Mathematics and Informatics, BAS, and the State Agency for Information Technologies and Communications). Until now, the library is used in several cross-media, ubiquitous and technology-enhanced learning applications (Paneva-Marinova et al., 2009).

The key for the current release of BIDL is the efficiency and the provision of strictly designed functionalities, powered by a long-term observation of the users' preferences, cognitive goals, and needs, aiming to find an optimal functionality solution for the end users. A special attention was pay to content creation, preview, search and administrative services, trying to cover a wide range of possible solutions. Moreover, the BIDL semantic content description orders the specification of unique descriptive scheme for iconographical art content, covering the rich semantic, identification and technical features of the iconographical objects.

In this paper we makes for the first time a complete presentation of the new release of "Virtual Encyclopaedia of the Bulgarian Iconography" multimedia digital library, passing from the semantic description of the iconographical art content to the BIDL architecture and functionalities, offered to the end users. During the BIDL development our main objectives are to give the users tool, providing opportunity to access, observe and compare valuable Orthodox iconographical specimens in their historic context, so that some yet undiscovered treasured of the Orthodox iconography be manifested.

2. SEMANTIC OF THE ICONOGRAPHICAL ART

The need for effective retrieval of the icons of East Christian Iconographical Art in BIDL is motivated by the increasing number of digitized iconographical objects. For the solution of this problem we develop *domain ontology for the East Christian Iconographical Art*. This ontology is used for the semantic metadata description and indexing of the iconographical art content. Similar work is done in (Tzouveli et al., 2008). It determined semantic classification for the Byzantine icons. This classification is used for icon separation on semantic regions in order to provide face detection, analysis of the facial characteristics and sacred figure recognition.

The conceptualization and formal presentation of the iconographical art semantic posed specific challenges for our team of ontologists, art domain specialists and DL content creators. Several problems in "Icons" domain formalization appeared. These challenges are mainly related with:

- Determining the set of separate ontological sub-structures of the iconographical object domain, the iconographic school, the author of iconographic objects, the iconographic character/scene, etc.;
- Determining in an unique way the descriptors of the different types of iconographical objects (icon, wall-painting, miniature, plastic iconographic object, etc.) according to accepted canons of the Orthodox painting;
- Reducing the complexity of the structures that describe different aspects of the iconographical object domain (especially for technological specifics, hierarchy of characters, descriptions of scenes, etc.) without loss of important content;
- Presenting relations between classes and constructing their complete network;
- Defining in an unique way the domain rules, axioms, constraints and facts (because of the incompleteness, inaccurateness or subjectivity of the existing information, presenting iconographical art domain);
- Creating standardized and consistent descriptions of iconographical objects following the available standards for cultural heritage content presentation.

In our ontological model the iconographical art world is described by three "thematic entities" (also called levels of knowledge). Every one of these entities is enriched with a set of sub-levels, covering wide range of characteristics. The first one is the "Identification" entity, which consists of general data identifying aspects such as IO title, type, author, its clan, iconographic school, period, dimensions, current location and source, and IO object identification notes, author's clan and biography, and iconographic school description (see figure 1).

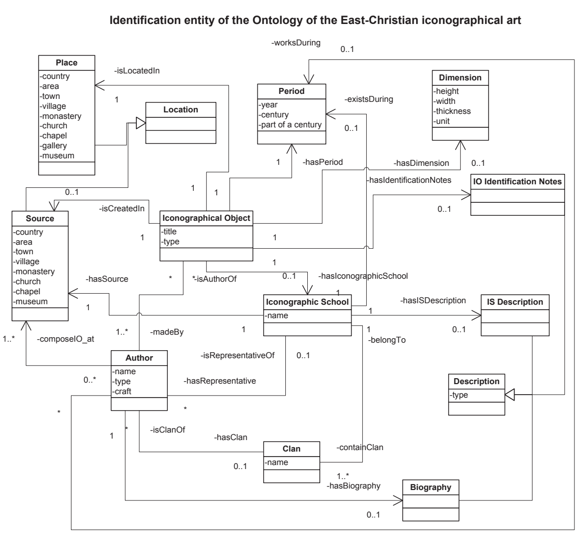

Figure 1: Identification entity of the Ontology of the East-Christian Iconographical Art

The second entity (see figure 2) covers information concerning the descriptive details of the theme and forms of representation, providing a better understanding of the content.

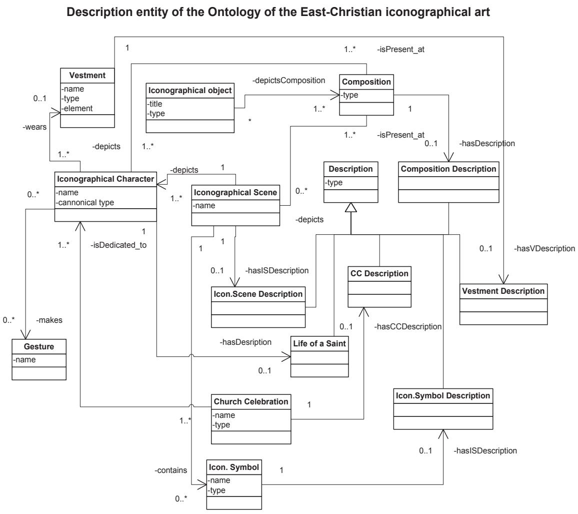

Figure 2: Description entity of the Ontology of the East-Christian Iconographical Art

The third entity (see figure 3) includes technical information revealing iconographic techniques, base materials, varnishes, gilding, etc., used in the creation of the iconographical object/collection, and also concerning examinations of the condition, such as diagnosis or history of the conservation treatment (Pavlova-Draganova et al., 2007b).

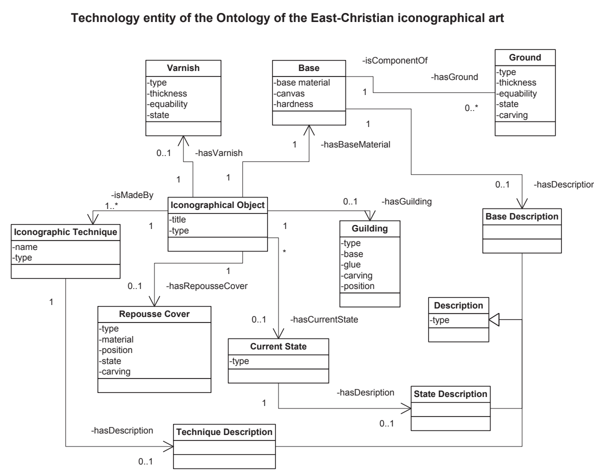

Figure 3: Technology entity of the Ontology of the East-Christian Iconographical Art

These main entities and their metadata values are supported, documented and provided by the scientific diagnosis, which has been applied to the iconographical objects and collections (Pavlova-Draganova et al., 2007b).

The interpretations of the iconographical knowledge are not considered isolated from the standards and specifications in the field of representation of cultural information because the goal is to maximize the reusability and portability of the designed ontological model. The most significant new development is the

CIDOC Conceptual Reference Model (CRM), "object-oriented domain ontology" for expressing implicit and explicit concepts in the documentation of cultural heritage. During the creation of the "East Christian iconographical art" ontology we observe the conceptualization approaches of CIDOC CRM ontology. We use part of its concepts and properties in our ontology. We extend another part in order to make it fit the iconography domain. For example, our "Iconographical Object" class is a sub-class of CIDOC CRM E22 -- Man-Made Object, our "IO Author" is CIDOC CRM E21 – Person, our "Clan" is CIDOC CRM E74 – Group, etc. The juxtaposing approach and a rich set of examples are included in (Paneva et al., 2007).

To represent efficiently the iconographical annotation framework and to integrate all the existing data representations into a standardized data specification, the "East Christian iconographical art" ontology need to be represented in a format (language) that not enforce semantic constraints on iconographic data, but can also facilitate reasoning tasks on this data using semantic query algebra. This motivates the representation of this ontological model in Web Ontology Language (OWL). OWL facilitates greater machine interpretability of Web content than that supported by XML, RDF, and RDF Schema by providing additional vocabulary along with a formal semantics. Knowledge captured from iconographic data using OWL is classified in a rich hierarchy of concepts and their inter-relationships. OWL is compositional and dynamic, relying on notions of classification, reasoning, consistency, retrieval and querying. We investigated the use of OWL for making our ontology using Protégé OWL Plug-in.

3. BIDL ARCHITECTURE

The architecture of the "Virtual encyclopaedia of Bulgarian Iconography" multimedia digital library contains two main service panels *Object data management* and *Administrative services* (see figure 4), jointed to a Media Repository and a User Profile Repository.

The *Object data management panel* refers to the activities related to content creation: add (annotate and semantic indexing), store, edit, preview, delete, group, and manage multimedia digital objects; manage metadata; search, select (filter), access and browse digital objects, collections and their descriptions.

The *Administrative services* panel mainly provides user data management, data export and tracking services. User data management covers the activities related to registration, data changes, level set, and tracking of the user. The export data services provide the transfer of information packages (for example, packages with BIDL objects/collections, user profiles, etc.) compatible with other data base systems. For example, with these services a package with objects could be transported in an XML-based structure for new external use in e-learning or e-commerce applications. The tracking services have two main branches: tracking of objects and tracking of users' activities.
The tracking of objects watch the activities of add, edit, preview, search, delete, selection, and group of objects/collections in order to provide a wide range of statistic data (for frequency of service use, failed requests, etc.) for internal use and generation of inferences about the stability and the flexibility of the work and the reliability of the environment. The tracking of users' activities monitors user logs, personal data changes, access level changes and user behaviour in the BIDL.

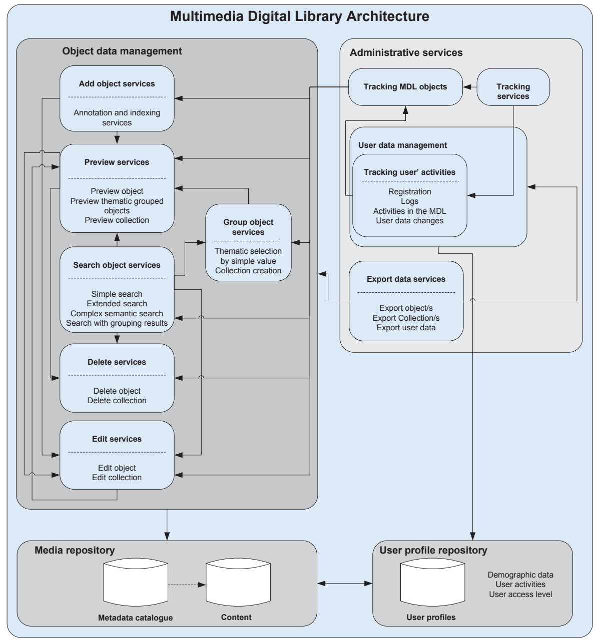

Figure 4: BIDL architecture

For every object all semantic and technical metadata are saved in the Media repository. These metadata are represented in catalogue records that point to the original media file/s associated to every object.

The User profile repository manages all user data and their changes.

4. BIDL FUNCTIONALITIES

4.1 Content Creation

The main part of the content creation process is the annotation and semantic indexing of digital objects in order to add them to the library repositories. The entering of technical and semantic metadata for a multimedia digital objects in the "Virtual encyclopaedia of Bulgarian Iconography" MDL is implemented through different automated annotation and indexing services (Pavlov et al., 2010).

The technical metadata, expressed in Dublin Core, are attached to every multimedia object automatically. They cover the general technical information, such as file type and format, identifier, date, provider, publisher, contributor, language, and rights.

An annotation template is implemented for the semantic description of iconographic objects. The template provides several options for easy and fast entering of metadata:

- Autocomplete services (All used (already entered) field values are available in a special panel for reuse.) (see fig. 5);

- Automated appearance of dependencies coming from the relations of the defined classes' (concepts) in the Ontology of East Christian iconographical art. (All main relations and rules expressed in the iconographical ontological structure are incorporated during the development of the annotation template);
- Example: If the value of the field **Region** is *Blagoevgrad*, when we start to complete the field **Town/Village**, all the available values in the MDL for towns/villages in the Blagoevgrad region will appear and can be selected by the annotator. All new field values are available for use after their first entering.

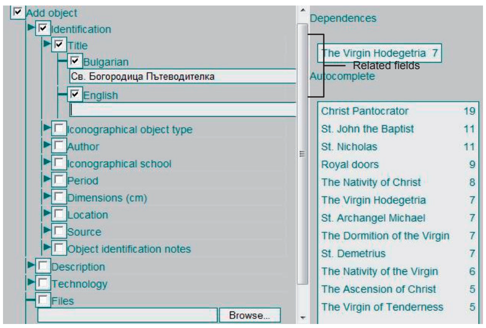

Figure 5: Part of the annotation template for an iconographical object

- Bilingual data entering with automated relation between the relevant values in different languages (see fig. 5);
- Automated appearance of the number of the used field value, providing regular data tracking (see fig. 5);
- A tree-based structure of the annotation template. Only checked fields are displayed for entering metadata (see fig. 5);
- Possibility for adding more than one media for one metadata description in order to create rich multimedia digital objects;
- Reuse of an already created annotation for new iconographical objects: the new media object has to replace the older one, the annotation is kept and the new iconographic object appears after saving;
- Automated watermarking of the image and video objects;
- Automated resizing of the image and video objects;
- Automated identification of file formats;
- Automated conversion of the audio, video and text objects in a format suitable for Web-preview.

After saving a new iconographical object, a special machine traces for the appearance of dictionary terms in the object data. If some terms are available the machine adds links to their explanations. In the case of entering a new dictionary term, its presence in the available objects is discovered automatically and a link is added.

In order to avoid duplicate image objects a service that checks the similarity between images is provided. It uses an algorithm that caching images for optimizing their compare (see (Pavlov et al., 2010)). Similar works for similarities calculation is proposed in (Kushki et al., 2004).

4.2 Content Presentation

During the development of the content presentation services a profound analysis was made of content selection and preview possibilities in order to satisfy the user's needs. First we had to determine the preview possibilities of a separate iconographical object and its components and after that the preview of grouped objects (Pavlov et al., 2010). Figure 6 depicts the view of separate iconographical object.

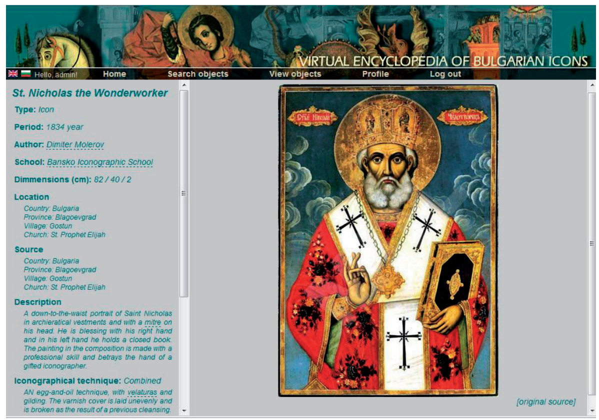

Figure 6: Saint Nicholas the Wonderworker, icon painted by Dimiter Molerov, Bansko Iconographic School

The visualization of the rich semantic description of the separate iconographical object is determined through hidden parts appearing in a new window after link selection. This possibility is used mainly for the long author's biography/school descriptions and for the dictionary terms. Parts of the descriptive data field are also hidden, but their values are available for searching in special forms.

The left frame of the preview window shows the description of the iconographical object. In the right frame the media/s object/s is/are situated. There appears a link to the original media source. The shown media object is stamped through watermarking technique.

During the development of object grouping services the main iconographic ontology classes are selected as object grouping criteria. For example, there can be a preview of the available iconographical objects, grouped according to their title, author, iconographic school, used technique or base material. Using another grouping option the user can see separately a list of all the iconographers (authors), and selecting one of them he can see additional biographic information and the collections of their work. A similar preview is available for the iconographic schools and regions/towns of physical object location.

The grouping option related to the presented content is implemented by the grouping of objects by depicted iconographic scenes, characters or canonical character types. Their presentation is based on the taxonomies of iconographical characters and iconographical scenes expressed in the ontology of East Christian iconographical art.

Every user can create his private collection of selected objects after search activity. Rich search possibilities are available in order to assist collection creation. The user can write the collection's title and short description. He can also select its status: private or shared with other users. New objects for a collection appear automatically after their entering.

4.3 Content Search

BIDL provides a wide range of search services, such as keyword search, extended keyword search, semantic-based search, complex search, and search with grouping results. Their realization was based on querying action to the BIDL knowledge base using mainly the structural branches of the "East Christian iconographical art" ontology. Moreover, five types of conditions for the results set are meant:

- "objects having value $= v$ for characteristic c "
- "objects having value $\neq v$ for characteristic c "
- "objects having numeric value $\geq, \leq, >, <, or = v$ for a characteristic c ". In the search templates you could search iconographical objects with precise date or period. The period could have concrete beginning and end date with a year's and/or century's (incl. parts of century as the beginning of century X, the middle of century X, the end of century X, the first half of century X, the second half of century X) values. In the Ontology of East Christian iconographical art the relations of year's and century's values (incl. its parts) are defined with rules.
- "objects having characteristic c "
- "objects NOT having characteristic c "

The search services support content request and delivery via index-based search and browse of managed content and its description.

4.4 Administrative Services

The *Administrative services* panel mainly provides user data management, data export, tracking services, and analysis services. The user data management covers the activities related to registration, data changes, level set, and tracking activities of the user. The tracking services have two main branches: tracking of objects, tracking of user' activities. Figure 7 depicts an example.

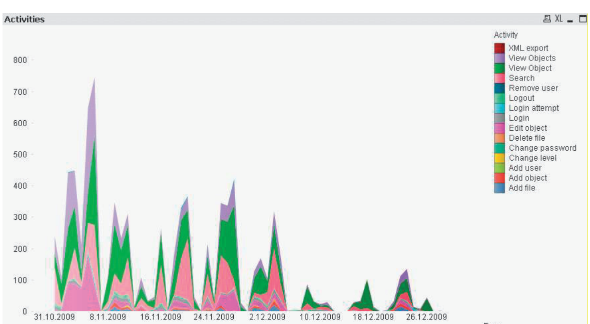

Figure 7: Users' activities during the period 10-12.2009

The tracking of objects spies on the activities of add, edit, preview, search, delete, selection, export to XML, and group of BIDL objects/collections in order to provide a wide range of statistic data (for frequency of service usage, failed requests, etc.) for internal usage and generation of inferences about the stable work (stability), the flexibility, and the reliability of the environment. The tracking of user' activities spies user logs, personal data changes, access level changes and user behaviour in the BIDL.

The QlickTech® QlinView® Business Intelligence software is the analysis services provider. It is connected to the BIDL tracking services and objects data base by preliminary created data warehouse.

The ETL (Extract, Transform, Load) is completely automatic process and is performed by administrator request.

The QlickTech® QlinView® Business Intelligence Software is deployed in order to provide fast, powerful and visual in-memory analysis of the data in the warehouse. It is a data access solution that enables you to analyze and use information from different data sources. It is based on online analytical processing (OLAP), which provides an approach to quickly answer multi-dimensional analytical queries (Codd et al., 1993).

Figure 8 depicts an example of PIE diagram for canonical sub-types analysis.

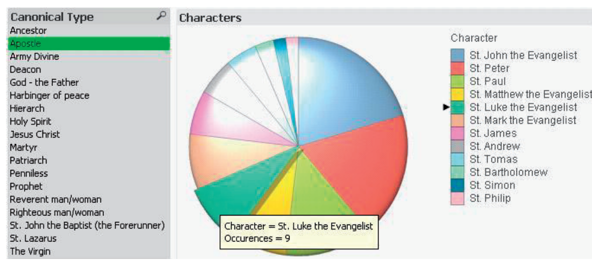

Figure 8: PIE diagram of canonical sub-types for *Apostle* canonical type

The variety of generated statistic information about BIDL data using QlickTech® QlinView® provides a rich extension of the tracking services and the base for profound analysis of extracted data.

The export data from the administrative services panel provides the transfer of information packages (for example, packages with BIDL objects/collections, user profiles, etc.) compatible with other systems managing data bases. For example, with these services a package with BIDL objects could be transported in a XML-based structure for a new external usage.

5. CONCLUSION AND FUTURE WORKS

Undoubtedly, the idiosyncratic art and exceptional values of the East Christian icon have to be made available in the global information medium. Its virtual presentation has to be executed through the best tools and techniques in other to continue to write traces in the history of the world fine arts. This paper presented the "Virtual Encyclopaedia of the Bulgarian Iconography" multimedia digital library and the developers' effort to build an applicable environment for cultural heritage exhibition.

Nowadays, BIDL includes several hundred specimens of Bulgarian iconographical objects from different artists, historical periods, and schools. There are also incorporated information objects, presenting iconographic techniques, authors' biographies, schools' history, terms vocabulary, etc. Several users created and driven collections are shown (for example, the unique collection of pencil-drawings of Zacharya Tsanyuv or the rich collection of icons from "Saint Trinity Church" in Bansko, etc.). The BIDL specimens are in the possession of the Bulgarian Orthodox church and the originals are currently exposed and freely accessible in acting Bulgarian churches and monastery.

The research in the field of iconographic art virtual presentation is supported by several international and national projects (for example, LOGOS project, SINUS project), mainly using the BIDL content for e-learning purposes (from formal and specialized professional education to self-training or personal cultural investigations). The SINUS project is 3-year national project that aims to demonstrate creative learning-by-doing through active learners' authoring of specific learning materials on Orthodox iconography, using multimedia and information resources delivered through BIDL. The main SINUS user groups are the developers of various learning resources and the consumers of those learning resources (i.e. academic users, researchers in the target learning domain, non-academic users). The users' group of BIDL is wider than defined in SINUS. BIDL functionality aims to serve iconographical art specialist and non-specialist. The group of specialists is composed by scientists who study Orthodox iconography professionally and search for specialized information on the observed iconographical objects. The group of non-specialists has interests and wants only to learn more about the iconographical objects. The current release of BIDL supports four users' levels: administrators, content editors, specialist viewers and non-specialists viewers with different privileges and access rights.

The future BIDL extensions are related to the content enrichment and the inclusion of wide range of artefacts of the Balkan countries and particularly Greece. In BIDL will also be included services for aggregating iconographical content for the European digital library EUROPEANA, thus providing possibilities for pan-European access to rich digitalised collections of East Christian iconographical heritage.

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FINDING YOUR WAY IN WIKI-BASED DIGITAL LIBRARIES: THE GOOGLE WAY

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KEY WORDS: Usability and interface design for CH applications, HCIR, exploratory search, users' perspective

ABSTRACT:

This paper addresses the topic of discovery and of users' explorative search behaviour in an online digital library. To this end, it reports the results of the user evaluation of a digital library for identification tools that was developed as part of the eContentplus project KeyToNature (K2N). These results show that users apply what we could call a "Google"-like search strategy when searching for information in a digital library and seem unable to find and retrieve information in other ways although the interface they are interacting with supports other interaction modalities.

1. INTRODUCTION

In this paper, we present a case study whose aim was to perform the usability evaluation of the digital library of a natural heritage application. While performing it, some issues specifically related to users' search behaviour and strategy when using this digital library arose. We discuss them here as they seem interesting to us. The digital library in question is a database which allows the search for text, images and sounds (of certain animals, like birds, for instance). There are also some technical issues related to it, namely some interoperability concerns, as the application that will be analysed in this paper is the common interface of several digital library applications using different standards (i.e., Linneaus, Frida, etc.). These issues are however not the focus of the present paper.
As previously discussed by Loizides and Buchanan (2009), when looking for information in a digital library users have to perform what they have called a "document triage".
This study builds on this knowledge by presenting some experiments aimed at demonstrating the applicability of this principle within the context of source selection in a Wiki-based digital library for natural heritage. More precisely, it shows how documents are selected for further investigation not, as in (Loizides and Buchanan, 2009), on the basis of some of the elements they present (i.e., length, headings, initial page, etc.), but on the basis of their relative position in the result list that is returned by the digital library software once an initial query has been submitted. Also in our case, then, as in Loizides and Buchanan's study (2009), searching becomes a mainly visual endeavour where attention is captured by some specific criteria like the potential relevance that is assigned to a given document by the users. In our study, what is driving attention and document selection is the expectation that the library works and that the documents are prioritized as in Google. This Google-like way of searching for information biases users' expectations and prevents them from serendipitous discovery (Toms and McCay-Peer, 2009).
The paper is structured as follows: first (Section 2), we present an overview of previous work in order to contextualise our study. Then, in Section 3, we briefly introduce KeyToNature (K2N), our eContentplus project aiming at the development of electronic tools (the so-called identification keys, see further) to identify biorganisms as a way to promote biodiversity education from primary school to university. In Section 4, we outline in details our methodological approach, experimental protocol and the results we collected. Section 5 discusses our findings.

2. PREVIOUS WORK

The planning and the implementation of digital libraries demand a plethora of studies to assess the final product adequacy to the users' needs. As observed by Ferreira and Pithan (2005), the conceptual support of digital libraries studies can be found in Information Science (IS), for what concerns the studies about information needs and user's behaviour during the information search and use processes, and in Human-Computer Interaction (HCI), for the usability studies.

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The strand supported by IS can be investigated both through quantitative and qualitative methods. Qualitative assessment methods utilize huge amount of data and are performed mainly through deep log analysis, usage statistics, Web analyzers (i.e., Google Analytics). The Centre for Information Behaviour and the Evaluation of Research (CIBER)* in the UK has published a fair number of studies on the information-seeking behaviour in digital libraries particularly by the Net Gen (CIBER, 2007; Nicholas et al., 2009; Williams and Rowland, 2007), i.e., the researchers of the future, by using the deep log analysis.

Qualitative assessment methods (namely, questionnaires, structured or unstructured interviews and focus groups) are also common to investigate information searching behaviour. Case (2002) undertakes a systematic survey of the research into this topic before the year 2000. Manifold studies have followed since then. Haglund and Olsson (2008) cite the most relevant ones. They also stress the importance to combine observational and ethnographic methods in the qualitative digital libraries assessment.

Recently, Loizides and Buchanan (2009) have also explored users' navigation behaviour in a very deep way by evaluating the impact of common visual document features on users' behaviour during document triage.

The strand conceptually supported by HCI uses exclusively qualitative methods to evaluate usability and users' satisfaction in digital libraries. The number of studies concerning this issue is overwhelming. To date, the HCI bibliography database indexes over 55.000 publications on this topic.

To perform our usability study we decided to use a combination of qualitative and quantitative methods, validating the results derived from a participant observation with the analysis of users' eye tracking and recordings of their navigation behaviour (see Section 4).

3. THE KEYTONATURE PROJECT

KeyToNature (K2N) is a 3-year project which started in September 2007 and is funded by the European Commission under the eContentplus Programme. The main objectives of the project are to (Martellos and Nimis, 2009):

- Increase the access and simplify the use of e-learning modules and tools to identify biodiversity.
- Address the issue of the interoperability of digital content.
- Optimize the pedagogic efficacy and the quality of biodiversity educational content.
- Give more value to the existing educational content by means of multilingual and easy-to-access content.
- Suggest best practices to avoid the barriers associated to the use, production, discovery and acquisition of interactive systems on bio-organism identification.

KeyToNature offers its users an integrated access to a unified and complex set of biodiversity data and repositories (which are normally fragmented and difficult to access by individual users) through the KeyToNature Web portal**. This portal is a Wiki-like environment which integrates general information about the project, functionalities such as news and events, the teachers' handbook, several country portals and a searchable repository of identification keys. Additionally, each country has a separate country page which functions as a national portal that contains information about the project in the local language as well as a series of additional biodiversity resources, tips for classes and a link to the searchable database of identification keys. Each country portal also provides content for teaching and learning biodiversity at a local level, local news and resources.

One of the main functionalities of the KeyToNature portal (and of each country portal) is to offer its users identification keys. From the KeyToNature perspective, "identification keys help users to identify a given set of species using a given type of media in a given language" (Hetzner et al., 2008, p.46). More precisely, identification keys are e-tools, mostly dichotomous or multi-access, which are used to identify a given biorganism on the basis of some of its features. For instance, if a user wants to identify a certain flower knowing its colour and shape, they are presented with a series of binary questions which guide them into the identification of the name of the flower they are interested in. The key indeed uses a matrix of species and identification characters and presents identification choices in simple yes/no questions that can be skipped. The software uses an algorithm to calculate the next best choice for the quickest identification (smallest number of questions). The query interface is mostly dichotomous which means that at each step the user is asked to select one of the two characters that are given to identify the organism (e.g., "Has the animal a black spot behind its eye?" "Yes" or "No"). Depending on the binary answer that is given, a different path is automatically generated by the key which deductively brings the user to identify the organism, eventually. In order to facilitate this decision-making process, iconographic and auditory (in case of animals) elements are provided as well.

The identification keys developed by KeyToNature are highly tailored to the needs of each particular target group. Such flexibility allows KeyToNature to even develop keys to identify plants that grow in a specific school garden or street.

Because of the high specificity and complexity of searchable data and metadata, it is important that the KeyToNature portal allows users to search its database in an efficient and user-friendly way. This is why a series of usability tests were carried out on a selection of country portals. Not surprisingly, some of the main findings have to do with the ways users search for information and try to find their way in these Wiki-based portals.

4. STUDY DESIGN

As part of the objectives of the KeyToNature project, the Italian*** and the Dutch**** national portals were evaluated with users to test their usability. They, along with the other 11 national portals, are based on the same Wiki technology, although their content significantly changes depending on the kind of target audience they address (i.e., all national portals mainly target school teachers and pupils, but the content within each portal also reflects differences in the school system and organization of every country involved in this project).

The Italian portal was tested by 5 Italian native-speaker users among which a biologist (but not a teacher, nor a botanist), three teachers (but of Italian) and one journalist, all aged 30-60. So, none of the selected users had a specific competence in the biodiversity domain.

They underwent a participant observation during which they had to perform 9 predefined tasks, 2 of which were specifically

* http://www.ucl.ac.uk/ciber/peoplenicholas.php
** http://www.keytonature.eu/wiki/Main_Page
*** http://www.keytonature.eu/wiki/Italy
**** http://www.keytonature.eu/wiki/Netherlands

addressing this search strategy issue. Examples of such tasks include the following:

You are a botanist. You have found a plant you do not recognize. You want to discover its scientific name. What do you do?

In order to fulfil this task, test subjects had to "discover' the link to the digital library present in the portal and search through it for the required information.

All interactions were recorded using CamtasiaStudio 6. While performing each of the tasks, users were asked to verbalise whatever they were looking at, thinking, doing, and feeling. This technique, known as the "think aloud" protocol, enables observers to see first-hand the process of task completion (rather than only its final product). Observers at such a test objectively took notes of everything that users said, without attempting to interpret their actions and words.

To assess the search strategy adopted by our subjects, we examined each recording qualitatively to identify their searching behaviour. This qualitative approach was coupled with a quantitative analysis using a series of open and closed questions by which users where assessing the overall portal.

The Dutch portal was tested by 5 secondary school biology teachers, aged 30-55. The tests took place at the usability lab of the Centre for User Experience Research, in Belgium, and consisted of a participant observation during which each test person had to perform 9 predefined tasks, which were however different from the ones previously mentioned. Of these tasks, 3 were addressing the search strategy issue under investigation in this paper.

The reason why we tested more search-driven tasks during the Dutch usability evaluation than the Italian one has to do with the selected users' profiles. For the Dutch evaluation, we were indeed able to recruit high school biology teachers, who are teaching identification searches and techniques using traditional methods (like pen-and-paper and on-field trips) to their students. It was impossible to reach a similar user group for the Italian national portal because the usability evaluations were carried on in Belgium where we were not able to recruit biology teachers who were also Italian native–speakers. Testing their language knowledge has never been the focus of this evaluation, and language proficiency is also not necessarily a predictor of their knowledge of the specific domain the page focuses on, i.e., biodiversity information. However, since each national portal provides information in each country specific language, it was necessary to bypass the language issue in order to be able to fully concentrate on the users' searching behaviour and their domain specific knowledge.

The choice to limit testing to 5 users per national portal is in line with Nielsen's specifications for usability evaluation (2000): so, we could identify up to 85% of the possible usability problems during a single and fast evaluation round before redesigning the portal.

During the Dutch tests, the "think aloud" protocol was also employed. The test sessions were audio and video taped; besides, all interactions were recorded using Tobii Eye Tracker.

4.1 Results

When asked to identify/determine a certain organism, users expected to find a search engine that would allow them to type a search term, for example the name of an organism (like quercus) and retrieve as search results all the keys where such an organism is to be found. To perform this task, both (actually all) national portals contain a digital library (i.e., a database) of the identification tools developed, approved or recognised by the project (Fig. 1).

Figure 1: The K2N digital library for identification tools

The first problem users encountered was however the difficulty to find the link to these identification tools. This is on each portal homepage, somewhere in the middle of the page, but it is indicated differently in each portal (Fig. 2 and Fig. 3).

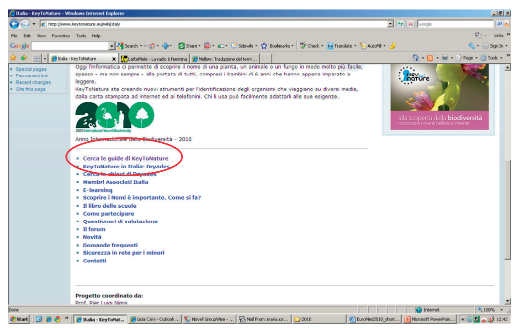

Figure 2: The location of the link to the identification tools on the Italian portal

The current search engine does not allow users to enter a search term or any keyword related to such a term, what seems to better accommodate users' typical search strategies. For what we were able to observe, users tend to prefer a Google-like search engine and search strategies, thus they expect to be able to find information that accommodates to this already internalised way of searching for information, i.e., by using a search engine that allows them to enter a term such as the name of an organism and which retrieves all the existing keys where such an organism appears.

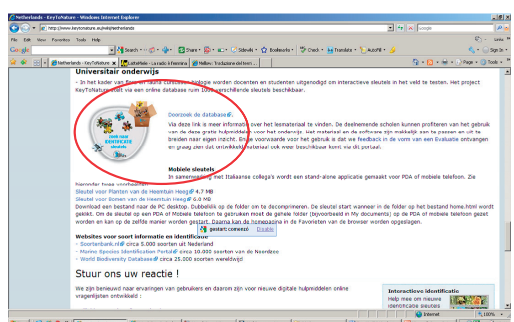

Figure 3: The location of the link to the identification tools on the Dutch portal

Searching the KeyToNature library indeed remains a difficult and unclear operation for most users. Firstly, for users it was not clear that they needed to search the database to retrieve keys and, most importantly though, how they eventually might get to it (see above). Secondly, they did not understand what to expect within the database, once found. Especially for new users who may not be acquainted with KeyToNature at all, it is important to use clear labels describing each possible operation a user may perform rather than extended explanations. Each label should clearly tell users what they are supposed to find under it if they click there. So, the anchor "Search the database" (Fig. 4) is definitely not a good way to support users' exploration and search behaviour. Finally, most users may not even bother to click on the link (i.e., http://www.keytonature.eu/wiki/Find_identification_tools) because it is not easily recognisable as a link (unless you place the mouse on top of it: it is not even underlined) or simply because they do not recognise this page as the one they were expecting to have found. Eventually, users did not realise the particular function of this searchable database, and, as a consequence, the difference between this and the Wiki search box which is positioned in the middle of the left frame menu.

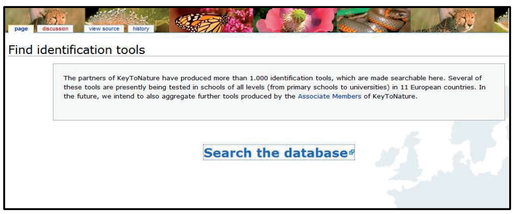

Figure 4: The "Search the database" page

Another problem users encountered by using the above mentioned library is that this is perceived as too detailed. As a result of a search query, the library indeed returns a list of very specific keys (e.g. trees of the city of Pordenone; trees and shrubs of the garden of the school G; see Fig. 5) that is simply too long and uninformative, rather than proving a really informative overview of the retrieved results. By being too specific, many of these results become irrelevant for the users who are not familiar with the specific (species of the) region the key refers to.

A way of making this overview more intuitive and easy to understand would require presenting less specific results by grouping the tools by categories like "plants of a generic Italian school garden", or by organisms. This would facilitate searching.

Figure 5: The high specificity character of the results retrieved from the library of identification tools

A final problem that was encountered by users when using the database of the identification tools is that the list it returns is too long sometimes (in Fig. 6, the search query returned 596 search results). Furthermore, it is also not possible to reorganise the information by characteristics such as language, geographic area or key availability. This makes it very hard to find a specific tool, certainly when the results retrieved are a few hundred (as in Fig. 3). This way of presenting information is counter-productive for users who get easily tired of scrolling down the page and always end up having a look at only the first tools of the table before they simply quit their search.

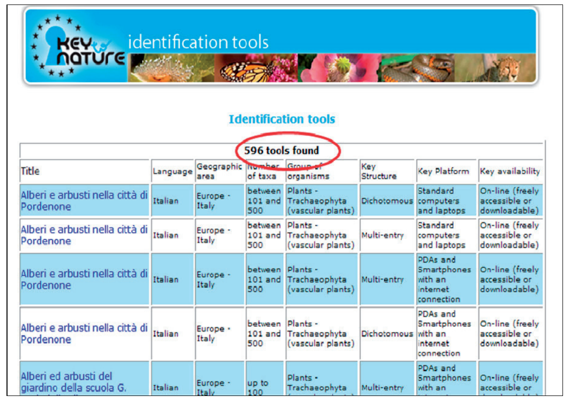

Figure 6: Number of results from the identification tools database

It was observed that users tend to adopt by default a certain strategy for reading such long tables: they read top-down, they instinctively stop after reading some items and therefore choose which item to select among the first ones that appear. Considering these reading and search strategies, it would be more appropriate to restructure the table so that searching becomes more intuitive, for instance by regrouping items into more generic categories (see also above). Alternatively, by providing a flexible way to visualise the information so that users can choose how the results are displayed. For instance, the tool could allow the possibility to display all the retrieved keys ordered by language or alphabetically or by availability, etc. in a similar way as information is displayed in mailboxes where e-mails can be ordered by sender, recipient, date sent, date received, etc.

5. DISCUSSION

The study reported in this paper shows that users tend to adopt what we have called a "Google"-like search strategy when searching for information in a digital library regardless of the possible other interaction modalities to find and retrieve information the library interface they are interacting with might support. This Google-like way presupposes a search field where keywords can be inserted and the creation, by the library software, of a ranked, relevance-based list of results matching those keywords. In our study, for instance, where results were not prioritized according to their relative matching with the original search criteria, test subjects reported to be confused and moreover to be unable to find the information they were looking for. What is even more striking is the fact that they were not trying to understand the way in which the library was supporting them in searching for information: they were

assuming by default that the Google-like way was the only and desirable way to look for information in this digital library.
This seems to be in line with a previous study by Loisides and Buchanan (2009) about the relevance users ascribe to documents during information seeking. They call this process *document triage* to indicate that users perform an initial judgment on the document potential relevance to their needs and that they repeat it many times before taking the final decision on which document to select. They show that users focus on only part of the documents they are searching, mainly the ones presented in at most the first two pages of search results, and that their search is mainly visual, i.e., driven by the visibility of the elements in the documents presented that they consider important for their information needs.

Although our focus is not on the decision-making process driving information search (i.e., the triage), nor on the features of the documents that prompt users' attention but on the model of searching subsumed by it, we can conclude that searching in a digital library is a visual activity that is supported by the expectations (or the mental model) adhered with by users. This expectation is what we referred to, throughout the paper, as the Google-way. There seems to be a gap between the user understanding ("It's like a Google search engine") and the actual content of the portals we tested (more like a meta-search): users do not seem able to understand how this is created. This is what caused users' expectations of the function's behaviour to be misled.

6. CONCLUSION

In this study, we performed the usability evaluation of a digital library for identification e-tools. Although this was not, as such, the focus of our analysis, we soon discovered that subjects encountered problems in looking for and finding information in this repository due to their expectations as on how this information should be presented to them. We noted that these users were so much Google-biased that they could not recognise (and appreciate) the modalities for retrieving information this Wiki-based repository was supporting and presenting to them.
Only two national portals (out of 11) were analysed as they were considered representative enough since they were well developed and rich in content. Different user groups were taken into consideration (namely, biologists and non-biologists), although this was mainly a functional and operational difference (due to the difficulties in finding Italian native-speaker biology teachers) rather than instrumental. It eventually did not seem to play a role, nor did it affect the actual and final user's behaviour in the search strategy adopted with the specific identification keys.

Still, many questions remain unanswered. For instance, "Were users too old to become accustomed to this medium?". "Would it have been a way to find another group for comparison?".
Although evaluating some of the other national portals does not seem to add much to the conclusions of the present analysis, extending and augmenting the target group including also students does. Several other studies on users' search behaviour (for instance, CIBER 2007) indeed point out that, although younger users are more proficient and skilled in the use of technology, they have very limited competencies and no critical attitude towards the information they find when it comes to the content they are looking for.

Our next step in the present research will be to understand if and how other forms of information finding may be enforced, like "serendipitous encounters" as in (Williams and Rowland, 2007) or a higher personalisation and sophistication level, and more social interaction, all features that are in line with the trends in Web 2.0, as discussed by Paterson and Low (2010) and to compare them with priority or significance criteria for listing results or documents as in Wikipedia or Google.

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DEVELOPMENT AND USER VALIDATION OF THE STERNA WEB-BASED SEARCH PORTALS

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KEY WORDS: Digital library, birds, semantic web, user validation, search portals

ABSTRACT:

This short paper presents the work-in-progress of the validation of the four search portals that were developed within the EU STERNA project. STERNA stands for Semantic Web-based Thematic European Reference Network Application and is a best practice network. It is funded through the European eContent*plus* Programme and aims at creating a distributed and networked information space on nature and wildlife, with a special focus on birds. In particular, this short paper describes the ongoing user validation process and its underlying methodology. This process includes four user validation phases and utilises three different evaluation methods: web-based WAMMI evaluations, focus groups as well as task-based usability tests. The short paper presents the application of these methods for evaluating four distinctive search portals on birds and the first findings of user validation which are available after completing the first round of WAMMI testing. Finally, the paper presents some of the lessons learned and the next steps to be taken in the user validation process.

1. INTRODUCTION

1.1 Background and motivation

STERNA - Semantic Web-based Thematic European Reference Network Application (http://www.sterna-net.eu) is a best practice network which is funded through the European eContent*plus* Programme. The project started in June 2008 and will end in November 2010.
STERNA is comprised of 13 European organizations, including research institutes, natural history organizations and technical institutions that collect and provide content on biodiversity, wildlife and natural history. According to the goals of the European Digital Library Initiative the project aims at creating a distributed and networked information space on nature and wildlife. Birds and bird-related information are at the centre of the STERNA digital library, which is composed of a variety of multimedia resources relating to bird species and their habitats.
STERNA serves as a showcase for using semantic web technologies and standards to link, search and access content from distributed and heterogeneous databases from European organizations of different type and size. It specifically wants to give cultural and scientific heritage institutions the opportunity to make their digital collections available in a light-weight fashion by setting up a distributed digital library that is based on semantic web technologies.
The main architecture of STERNA allows distributed querying of content at member sites based on metadata represented in RDF (Resource Description Framework) format and reference structures represented in SKOS (Simple Knowledge Organization System) format.

Through this networked architecture, along with its software-as-a-service concept, organizations are able to contribute and interlink their content without having to invest heavily in technical infrastructure. The underlying architecture also supports content providing organizations that favour the idea of institutional flexibility and autonomy. They decide on what data they would like to share, they do not have to change their local information structures and systems and their digital resources remain within their databases.
In addition to content providers, STERNA also addresses users that are interested in birds, i.e. bird and wildlife enthusiasts in the widest sense. Therefore STERNA tests and validates its approach against different groups of target (end) users. Based on four use cases we have developed four search portals which provide windows to STERNA for these target groups.

1.2 Aims and overview of related work

The aim of this short paper is to depict the development of the STERNA search portals, the ongoing user validation process and its underlying methodology and to present some interim evaluation results that are already available.
The work presented in this paper is relevant to Europeana and other projects conducted in the framework of the European Digital Library Initiative, such as the Biodiversity Heritage Library for Europe (BHL) or DL.org.

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2. STERNA USE CASES AND SEARCH PORTALS

2.1 STERNA use cases

The project's four use cases have been developed by four STERNA partners and address different target audiences: bird watchers; a young, digitally savvy audience; boaters and tourists at sea; and a general audience interested in nature and birds (the “humble rambler”). These were developed based on a template which also included one or more user scenarios, i.e. typical situations in which target users would make use of the STERNA information space and search for bird-related information. User scenarios are useful in better focusing the design and development process towards users' requirements (Bødker, 1999).

2.2 Target group specific search portals

The four use cases served as the basis for developing four distinctive search portals that address these target groups. While the search portal targeting a young, digitally savvy audience and the portal targeting tourists and boaters at sea have “simple” search functionalities, the search portal which is aimed at “professional users” (i.e. bird watchers) enables users to search for content on bird species in more than one way and to refine search results (faceted navigation). The search portal targeting a general audience also offers a silhouette driven search functionality to help users identify a particular bird.

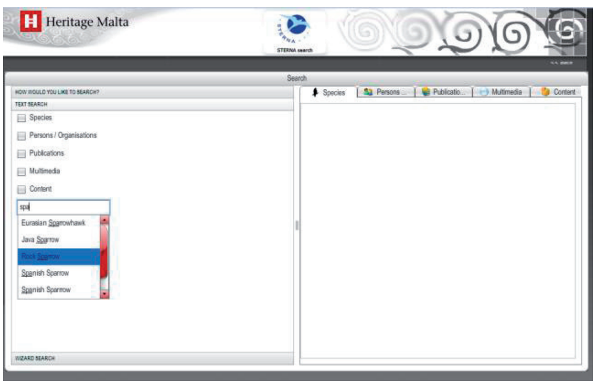

Figure 1: Search portal targeting a general audience: text search with a controlled list for help

2.3 Added value and comparison to other solutions

The STERNA search portals on birds share some features with existing web-based resources and portals on birds, but are also distinct from these. Other web-based resources and portals on birds are, for example, the Internet Bird Collection, Avibase, Neotropical Birds or the bird portals of the BirdForum and BirdLife.

The Internet Bird Collection (http://ibc.lynxeds.com) features videos, pictures and sound recordings and provides taxonomical information on bird species, including detailed geographical information on bird species. Users can also contribute multimedia information. Unlike STERNA, however, all content is hosted centrally on the servers of the Internet Bird Collection, whereas STERNA follows a federated approach, which supports institutional flexibility and autonomy of content providers. As members of the network, they decide on partial and controlled sharing of their content, while local information structures and systems are left intact and digital resources remain within their databases. This, in particular, can be an advantage for smaller organizations and institutions.

Bird names and taxonomy are the focus of Avibase (http://avibase.bsc-eoc.org/avibase.jsp?pg=home&lang=EN). The portal features vernacular names of birds in more than ten languages. A search can be made either by bird names or by geographical regions. Furthermore, Avibase provides direct links to external web resources for each species, including BirdLife International, Xeno-canto, ITIS and Flickr. However, in comparison to STERNA external sources are not able to directly add their content to Avibase. Therefore natural history organizations cannot use this platform to directly present their content.

Neotropical Birds (http://neotropical.birds.cornell.edu/), run by Cornell Lab of Ornithology, is a vast and growing resource on birds from the Neotropical region. The portal features all information types ranging from distribution maps and detailed species accounts to multimedia, such as sounds and pictures. The portal enables users to contribute information in several ways (http://neotropical.birds.cornell.edu/portal/contribute). Again, unlike STERNA, natural history organizations cannot present their collections on Neotropical Birds.

Bird Forum, one of the largest birding communities on the web, hosts a birds wiki called Opus (http://www.birdforum.net/opus/Birds_Portal). This encyclopaedia-like portal allows users to search for birds and birding locations, and also allows browsing by taxonomy. It is a user-driven wiki and thus invites users to contribute content.

Similarly the portal of BirdLife International also allows users to search for different information on birds (http://www.birdlife.org/datazone/species). The information here is managed by BirdLife International itself. Users can search for information on a particular species or group of species by different search criteria and filters, e.g. by searching for a particular bird family (listed in taxonomic order) or entering free text for a genus, species or common name. The search for common names is currently restricted to English only. The search can also be restricted by region/country or the IUCN (International Union for Conservation of Nature) Red List categories (e.g. extinct or endangered species).

While all these web resources provide a wealth of information, they do not offer the same scope of heterogeneous content and filter options that STERNA provides. For instance, they do not allow natural history organizations to present content, such as museum specimens, spanned drawings/plates, publications, or information on persons or organizations. Moreover, unlike STERNA these resources do not allow natural history organizations to add, enrich and manage content themselves.

Another alternative for Internet users would be to use Google, Wikipedia or Flickr to search for bird related information. However, these options often result in a lot of "noise" (i.e. less relevant information) and information that has not been validated. STERNA, on the other hand, specifically presents validated and trusted information via its search portals. Users know where the content came from and they are able to get in contact with the organization and/or creator if wished for.

Multilinguality is another aspect which differentiates the STERNA search portals from these solutions: STERNA allows users to perform searches in their own languages. This is particularly important when users search for birds using vernacular names. Users are also able to find relevant content in different languages, not only their own. The STERNA search portal for birdwatchers also offers additional search filters, such as searching for specific locations, persons or dates. Users can also view related content: For example, if a user clicks on the name of a specific bird collector, the user can also find related content to this person, such as articles written or specimens collected by him or her.

2.4 Relevance to cultural heritage sector and Europeana

Part of the content provided through STERNA is cultural heritage content, such as books, drawing or paintings, specimens or ethnographic information, and thus of interest for the wider cultural heritage sector. Also many of these species presented in STERNA are the focal points of both developed and indigenous cultures around the world. These species are vitally important and as such digitally storing and making accessible data on them brings them to public attention and may help to preserve them for the future.

Against this background some content from the STERNA information space will also be linked to Europeana (work in progress), thus enabling organizations, especially smaller ones, to link their natural heritage content with Europeana in a relatively easy and cost-effective way.

STERNA also invites new partners to become a part of the network (for free) and contribute their content. New partners can also set up their own search portals by using a standard set of tools and API functions that were developed within the project, and which should allow any web developer to build and install STERNA search functions on their own websites. This will enable them not only feature their own content but also the content of other STERNA partners.

3. USER VALIDATION METHODOLOGY AND PROCESS

It is important to note that the search portals developed are all prototypes, which are iteratively tested and improved through a series of user validation and subsequent refinement phases.

The ability to test the STERNA search portals in their development forms allows for problems to be identified and solved throughout the entire process. This prevents huge design and technical flaws appearing at a stage where it may be too late to correct them efficiently. Although the testing process is time consuming, due to it preventing major design and technical flaws it has the benefit of being both time and cost-effective in the long run.

The main goal of the target user testing and validation is to iteratively test and improve STERNA against the target groups as identified in four use cases. In particular, this includes the testing and improvement of the prototypes of these four use case search interfaces/portals in terms of a) the presentation of content and search results to users, and b) the usability of the search interfaces/portals.

User validation in STERNA follows the user-centred design approach for interactive systems. The idea of user-centred design is that the product should suit the user, rather than making users suit the product. User-centred design actively involves the user in all phases of the system design and development. In STERNA we use an iterative design approach where users are involved early on in the design and development process. The early and active involvement of users helps to avoid unpromising ―design paths” and to develop a deeper understanding of the actual problems.

The major principles of this approach are a strong focus on the actual end users and iterative design, which means that the search portals are designed, tested and modified repeatedly. (Baxter and Courage, 2005)

At the beginning of the project the user validation process and methodology for STERNA was laid out in detail in the project‘s internal Target User Test and Validation Plan. The STERNA iterative validation and development process encompasses four different phases:

- A first WAMMI test;
- Focus groups;
- Task-based usability tests; and
- A second WAMMI test.

Each of the four validation phases follows a specific structure that includes the preparations for testing, the actual execution and documentation of the tests, the analysis of user feedback and, finally, the improvement of the STERNA search portals based on this feedback. The focus of testing is both on the usability of the user interface as well as the presentation of content and search results to users.

Due to limited available resources, the WAMMI evaluation is applied for only two use case search portals: the portal targeted at bird watchers and the portal targeted at a young and digitally savvy audience. The more in-depth focus groups and usability tests are applied for all four search portals (however, the findings from the WAMMI evaluations are, if relevant, also considered for the other search portals).

Throughout the whole user validation process – from the initial planning and preparation to the conducting and analysis of the different user validation phases – the four user validation partners have co-operated closely with the partner co-ordinating the user validation activities.

Figure 2: The search portal for a general audience also offers a silhouette driven search to help users identify a particular bird

In the following sections, the user validation methods are described in more detail.

3.1 WAMMI evaluation

WAMMI (www.wammi.com) stands for Website Analysis and Measurement Inventory and is a web-based analysis tool for the testing and measurement of user satisfaction of a website or a web-based application.

WAMMI measures user satisfaction by requesting users to fill in an online questionnaire and compare their expectations against what they actually find on the web-based solution. Unlike other analysis tools, however, WAMMI does not only measure how users are rating a website or solution; it also compares the user reaction with values generated from a comprehensive reference database. This allows the comparison with other sites and solutions, and thus gives a better understanding of the quality of the tested solution(s).

User satisfaction is measured in terms of different usability characteristics: attractiveness, controllability, efficiency, helpfulness, learnability and the overall global usability.
For evaluating the STERNA search portals we developed an online WAMMI questionnaire that included the standard 20 WAMMI questions as well as additional fixed choice and open response questions. The fixed choice questions asked users about demographic data (e.g. age, gender, Internet usage or how often users watch birds), while the open response questions allowed users to comment on the ease-of-use of the search portals tested as well as to provide suggestions on how to improve them. (see www.wammi.com)

3.2 Focus group evaluation

A focus group is a qualitative research method that is usually conducted in the early stages of the design and development process, or even the pre-design phase of a system (in our case, this was already done by defining use case scenarios). Focus groups are conducted with a limited number of representative users in order to receive feedback on concepts, prototypes or products and to gather insights that are sparked by group interaction. A moderator steers the focus group discussion without discouraging the participants from expressing their thoughts. The discussion should not be too structured, so that comments are not discouraged. With focus groups we can identify opinions, attitudes and preferences from participants and learn better how end-users ―think and feel” (Chisnell and Rubin, 2008; Baxter and Courage, 2005; Morgan, 1996).
The main objective of the STERNA focus groups is to get feedback on the presentation of content and search results as well as the usability of the search portals. They should both identify shortcomings and problems as well as ideas and suggestions on how to improve the search portals. The findings and recommendations serve as input for the further improvement and refinement of the STERNA search portals.

3.3 Usability tests

In STERNA we apply the user-based usability test method, which includes a task-based usability evaluation, semi-structured interviews that are conducted after each test and a user satisfaction questionnaire to be filled in by each test user. Users are requested to perform real-life tasks, thereby evaluating the usability of the use case search interfaces, the user satisfaction with the presentation of content and search results delivered, as well as providing suggestions and ideas for further improvement.
At the beginning of each usability test a moderator introduces test users to the STERNA project and explains what is expected from them. Then the moderator hands out the tasks that they should perform during the test. Throughout the test users are video taped for documentation and analysis. All documentation and analysis are kept anonymous and confidential.
After the test, the moderator and the test users revisit the video documentation of the test in the form of a semi-structured interview, thereby allowing the users to reflect on the test and the search portal, and to provide further feedback (―post-usability test walk-through”). It also allows them to better explain to the moderator what they liked/disliked and their suggested improvements. Finally test users are requested to fill in a user satisfaction questionnaire (Dumas and Redish, 1999; Chisnell and Rubin, 2008; Albert and Tullis, 2008).

3.4 Refinement of use case search portals

Based on the user feedback derived in each testing phase, the search portals are improved and refined, taking into account the problems identified and the suggestions provided. In this way the STERNA search portals are iteratively tested and improved: as noted above, the search portal addressing the young and digitally savvy users and the portal addressing bird watchers are tested and refined four times; the other two search portals are tested and refined twice.

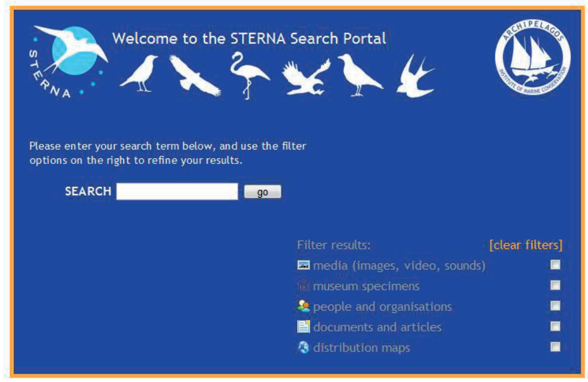

Figure 3: Text search and filter options of the search portal for boaters and tourists at sea

4. STATUS OF THE USER VALIDATION PROCESS AND INTERIM RESULTS

4.1 Status of user validation process

User validation of the search portals for the young, digitally savvy users and for bird watchers started with the first round of WAMMI testing in October and November 2009 respectively. User testing continued until late January 2010. In February 2010, we received the WAMMI evaluation reports as well as a content analysis of the user comments provided. Currently we are in the second phase of user testing where all four search portals are evaluated through focus groups.

4.2 Interim results of user validation (WAMMI 1)

Altogether 64 users filled in the WAMMI questionnaire for the search portal targeting bird watchers, and 94 users filled in the online questionnaire evaluating the search portal for a young, digitally savvy audience. In the first round of WAMMI testing both search portals scored below average in relation to the WAMMI reference database (that is the set of websites and solutions that were previously evaluated), with the search portal targeting young, digitally savvy users being considerably rated better than the search portal for bird watchers.
The search portal for bird watchers received a mean global usability score of 21.8, the other search portal a mean global usability score of 41.4 (on a scale from 1 to 100, whereby one is lowest and 100 highest; 50 represents the average of the reference database of tested websites and solutions). While they were rated below average, the search portal for bird watchers especially, it is also important to note that the tested search portals are prototypes in an early development stage. This is because we wanted to test the prototypes to identify problems early on and thus to make the design and development process

as resource and cost effective as possible rather than testing the final product.
For both search portals we received a considerable amount of user feedback, which further helped us in specifying the main usability problems of the search portals, as well as providing us with valuable suggestions on how to improve them further.
In the following sections 4.3 and 4.4, some of the results of the first round of WAMMI testing are presented.

4.3 WAMMI findings: search portal addressing a young, digitally savvy audience

Users rated the search portal relatively good, with a mean global usability (GUI) score of 41.4. Users were already quite satisfied with the efficiency of the search portal (mean usability (UI) score of 46.2), in particular in terms of its fast loading times. Users also generally considered the search portal easy-to-use. The lowest individual usability scores we received in terms of the attractiveness (mean UI score of 36.4) and the learnability and helpfulness (mean UI scores of 41.1 and 41.2 respectively) of the search portal.

Figure 4: The search portal for young, digitally, savvy users tested in the WAMMI evaluation

Younger users tended to rate the search portal slightly better than older users. For the 16-24 age group, for example, the mean GUI was 45 in comparison with 43.2 for the 25-34 age group. Female users also rated the search portal slightly better than male users, with a mean GUI score of 43 for female users in comparison to 39.5 for male users.
Overall many users thought that the user interface design and the way the search results are presented needed to be improved considerably. For example, many users were unhappy with the overall screen design (e.g. colours and backgrounds) and some of the icons that were used (especially the media icon, which showed a drawing, but when selected also listed audio and video results) and the display of the actual search results and content. In particular, users expected to go directly to the actual content when they clicked on a search result, instead of getting an intermediary page with an additional external link leading to the content. Narrow spacing and the position of links at the bottom rather than the top of the content pages were also frequently mentioned by users.
While users considered the search functionality as easy-to-use, some users also noted that they considered the search portal as too academic in its focus. Considering that the target group are young and tech savvy users, we have to make sure that the search portal will be more accessible in this respect and feature less academic content (such as metadata pages) and apply better filtering mechanisms to deliver more fitting search results for the target group.
Some users also remarked that they were unsure about the purpose of the search portal. For the refinement the search portal will have to be made more intuitive and make its meaning and purpose more apparent (for the test a separate introduction page was provided, which apparently was rarely read by users). This was also noted by test users of the search portal addressing bird watchers. On the other hand, some users also specifically praised the quality and authenticity of the content and search results provided.

Figure 5: Revised search portal after integrating findings from the first WAMMI evaluation

4.4 WAMMI findings: search portal addressing bird watchers

As was noted above, this search portal received a rather low mean global usability (GUI) score of 21.8. The search portal received the lowest usability (UI) scores in terms helpfulness (mean UI score of 19.8), followed by attractiveness (mean UI score of 20.6), learnability (mean UI score of 20.9) and controllability (mean UI score of 23.5).
Similar to the other tested search portal (see above), younger users tended to rate the search portal better than older users. For example, while the mean GUI for users from the 31-40 years age group was 26.9, it was only 19.4 from the 41-55 age group, and 11.3 for the 56 to 70 age group. Also, more frequent bird watchers tended to rate the search portal slightly better than users who rarely watched birds (i.e. less than 10 times a year).
The main problems associated with low scores on helpfulness and learnability were that users generally seemed to be unsure about the purpose of the search portal, which they also considered as not very intuitive and rather complicated to use. Controllability was also an issue noted by many users, as they found it difficult to navigate through the portal. Users particularly had problems with the _clear‘ and _edit‘ buttons when entering a search term. Also users were confused by the different search functions available, such as _keyword search‘ and _search string‘. The keyword search often did not deliver any results, which further frustrated users. Terminology was another issue, as some users found it difficult to differentiate between some terms (e.g. ―creator” and ―author”). In fact, a large portion of user comments focused on these aspects, which also might explain the relatively low scores in this respect. To improve the search portal users therefore suggested using a simple search function with providing an option for using an advanced search functionality, if necessary. Edit and clear functions for conducting a search should not be used at all; a

blank space with the possibility of writing the search term was suggested instead.

Figure 6: Revised search portal for bird watchers offering simplified and advanced search options

Attractiveness was another issue that users mentioned. For instance, users wanted the search portal design and the contents presented to be more visual, using more images and icons instead of presenting a lot of text.

5. CONCLUSIONS AND LESSONS LEARNED

5.1 Lessons learned so far

Many lessons have been learnt with the completion of the first phase of user testing.

A major lesson learned was that we found it very difficult to attract users in testing and actually filling in the online WAMMI questionnaires. As a result, the WAMMI testing period took longer than initially anticipated and we could finish testing only in late January 2010 (instead of December 2009 as initially planned). On the other hand, we were positively surprised about the large number of users who commented on the ease-of-use of the search portals, or who provided suggestions on how to improve them. Together with the results from the WAMMI reports and the content analysis of these user comments we were able to identify and specify major problems of our prototype search portals and also to gain valuable ideas and suggestions for further improvement.

Finally, we also learned that we need to better explain the purpose of the search portals to better manage user expectations. Although (as mentioned above) we briefly introduced the search portals in an introduction page before users entered the actual search portals (including some information inviting users to fill in the WAMMI questionnaires), many users apparently did not read these instructions, and were unaware of the purpose of the search portals and what to expect from them. For the revised search portals we therefore need to make the search portals more self-explanatory, and also provide some brief information describing their purpose on the individual search portals.

5.2 Next steps in user validation

Based on the user feedback from the WAMMI evaluation, both tested search portals were revised and improved, both in terms of the user interface design as well as the presentation of content and search results delivered.

Until June 2010 focus groups for all search portals were conducted, with the analysis of user feedback and further improvement of the search portals to be implemented until the end of August 2010. In September 2010 we will conduct the usability tests, to be followed by a second round of WAMMI testing in October 2010, which will complete the user validation process for STERNA.

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Digital Libraries and e-Preservation in Cultural Heritage

Part II

BUILDING LARGE HETEROGENEOUS INTERCONNECTED DIGITAL LIBRARY INFRASTRUCTURES: THE INTEROPERABILITY CHALLENGE

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KEY WORDS: Interoperability, Digital Libraries, Standard, Mediators, Interoperability issues, interoperability model

ABSTRACT:

Interoperability is a multi-layered and context-specific concept, crucial when building heterogeneous interconnected Digital Library infrastructures. It encompasses different levels along a multidimensional spectrum. Two key problems hinder the achievement of interoperability: (i) the heterogeneity of the exchanged information which covers all types of syntactic, structural, and semantic diversities among systems used to modelling information and (ii) the inconsistency between the use of the information as intended by its originator and the intended exploitation of it by the recipient. Building heterogeneous interconnected Digital Library infrastructures requires addressing all dimensions of interoperability including content, user, functionality, architecture, quality, and policy. In this paper a comprehensive study of the interoperability issues involved when building interoperable Digital Libraries is performed.

1. INTRODUCTION

As technology becomes more far-reaching and interconnected, interoperability has become critical. It ranges along a wide multidimensional spectrum: at one end of the spectrum we have data and metadata interoperability while at the other end we distinguish organizational, legal and policy interoperability.
Interoperability is a multi-layered and context-specific concept, crucial when building heterogeneous interconnected Digital Library infrastructures. It encompasses different levels along a multidimensional spectrum. Two key problems hinder the achievement of interoperability: *(i)* the heterogeneity of the exchanged information which covers all types of syntactic, structural, and semantic diversities among systems used to modeling information and *(ii)* the inconsistency between the use of the information as intended by its originator and the intended exploitation of it by the recipient.
Building heterogeneous interconnected Digital Library infrastructures requires addressing all dimensions of interoperability including content, user, functionality, architecture, quality, and policy.
This paper is organized as follows. Section 2 describes a number of application scenarios where several interoperability issues are outlined. Section 3 gives a definition of interoperability and identifies the sources of problems which hinder the interoperability among federated Digital Libraries. Section 4 describes some approaches to achieving interoperability. Section 5 identifies and describes several types of interoperability. The last section contains some concluding remarks regarding best practices when implementing interoperability solutions.

2. INTEROPERABILITY SCENARIOS IN THE CONTEXT OF INTECONNECTED INTEROPERABLE DIGITAL LIBRARIS

In this section we illustrate some typical scenarios which occur in the context of interconnected interoperable digital libraries and emphasize interoperability problems.

2.1 Metadata Harvesting

In the open, networked environment that encompasses multiple user communities using a multitude of standards for description of digital resources, the need for interoperability among metadata is paramount. To enable federated searches and to facilitate metadata management, much effort has been devoted to achieving or improving interoperability among metadata schemes/records. The metadata harvesting scenario is the most commonly implemented.
In this scenario, information providers (institutional repositories/digital libraries) make metadata about their collections available for harvesting. Service providers (harvesters) use this metadata to create value added services.
If the service provider wants to collect metadata from different information providers and integrate them in order to provide a uniform access to them different interoperability problems could arise. For example, if the different information providers adopt different metadata models their integration could become problematic. Even if a common metadata model is adopted some other interoperability problems can still arise concerning, for example, the syntax rules for how the elements and their content should be encoded, content rules for how content must be formulated (for example, how to identify the main title), representation rules for content (for example, capitalization rules), and allowable content values (for example, terms must be used from a specified controlled vocabulary).
Additional interoperability problems can arise related to mismatching of transfer protocols.

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To facilitate interoperability, information providers are required to supply metadata which complies to a common schema (for example, the unqualified Dublin Core Metadata Element Set). The harvesters must issue requests according to a protocol (for example, OAI-PMH (Lagoze & Van de Sompel, 2001)).
The metadata harvesting approach is adopted by Europeana, the European Digital Library.
From the service provider side, Europeana must interoperate with the memory institutions in order to obtain the metadata on which it offers its services. In order to achieve this goal, Europeana must be able to interact with the providers' DLs at a functional level, to obtain the metadata required. This is obtained by adopting a standard solution, namely the OAI-PMH protocol for harvesting. The protocol defines the services to be implemented on both sides, so that interoperability between Europeana and the content producers can be achieved. Once the data is acquired from Europeana, it has to be mapped from the original format to the Europeana Data Model (EDM). This mapping requires knowledge of the semantics of the source and target data models.
From the information provider side, Europeana will make its contents available through a number of APIs, each one addressing the needs of a particular category. These APIs will be used by consumers to obtain services from Europeana, and will be the result of negotiations between the involved parties.

2.2 Digital Library – User Interaction

Each Digital Library has its own policies; for example, policies for document acquisition, document management, access and use, loans, charges for access, etc.
On the other hand, the different classes of patrons (end users, librarians, administrators, etc.) interact with the Digital Library according to a profile authenticated at the registration time. In order for the patrons to effectively perform their tasks these must be consistent with the policies of the Digital Library.
The Libraries' policies and the working requirements of their patrons must be compatible.
Adequate representation formalisms for representing DL policies as well as patron's requirements must be adopted and appropriate consistency checking techniques must be implemented.
In addition, in the context of interconnected Digital Libraries, there is the need for the user credentials and profiles to be propagated across several Digital Libraries in order to allow a user authenticated in one Digital Library to operate in another Library which trusts the user Library. There is the need for the interconnected and mutually trusted Digital Libraries to be able to exchange user credentials and profiles in a meaningful manner.

2.3 User – User Interaction

Another very important form of interaction between users regards the so-called "user collaboration" based on Digital Libraries' resources (content and functions/services). In order to support collaboration between users across different mutually trusted Digital Libraries these must enable their users to interact among them directly or indirectly. To achieve this the users must be able to exchange meaningful content and to invoke and/ or combine compatible functions/services across different Digital Libraries. This means the ability to perform consistency checking between the invoked and/or combined functions/services.

2.4 Trusted Digital Libraries

In the context of interconnected Digital Libraries it is of paramount importance the harmonization of their policies concerning the very different functionalities/services supported by them in order to guarantee a seamless interoperation between their patrons. Therefore, formalisms to express Digital Library policies and techniques to check their compatibility and enforce them are very important in this scenario.

3. THE INTEROPERABILITY PROBLEM

From the IEEE definition which characterises it as "*the ability of two or more systems or components to exchange information and to use the information that has been exchanged*" it follows that in order to achieve interoperability between two entities (producer, consumer) two conditions must be satisfied: (*i*) the two entities must be able to exchange "meaningful" information objects; (*ii*) the consumer entity must be able to use the exchanged information in order to perform a set of tasks that depend on the utilization of this information.
Therefore, there are two sources of problems which hinder the interoperability between the producer and consumer entities: (*i*) Heterogeneity of the exchanged information objects; (*ii*) Inconsistency between the use of the information object as intended by the producer entity and the intended exploitation of this object by the consumer entity.

3.1 Heterogeneity of exchanged information objects

There are three types of heterogeneity to be overcome in order to achieve a meaningful exchange of information objects (Candela, et al., 2008).
First, heterogeneity between the native data / query language (of the consumer entity) and the target data / query language (of the producer entity). When this heterogeneity is resolved we say that syntactic interoperability between the two entities has been achieved.
Second, heterogeneity between the models adopted by the producer and the consumer entities for representing information objects. When this heterogeneity is resolved we say that structural interoperability between the two entities has been achieved.
Third, heterogeneity between the "semantic universe of discourse" of the producer and consumer entities (differences in granularity, differences in scope, temporal differences, synonyms, homonyms, etc.). When this heterogeneity is resolved we say that semantic interoperability between the two entities has been achieved.
Although these three levels of interoperability, syntactic, structural, and semantic allow a meaningful exchange of information objects, they do not guarantee that "real" interoperability between the two entities has been achieved as this implies the ability of the consumer entity to use the exchanged information objects in order to perform a set of tasks.
When the sole "meaningful" exchange of information objects is sufficient to enable the consumer entity to perform a set of tasks based on the exchanged information objects we can talk about "basic" interoperability between producer and consumer entities.

3.2 Mismatching between producer information resources and consumer needs

We distinguish two kinds of interoperability: partial and full interoperability.
By "partial interoperability" between two entities we mean that the consumer entity is able to perform a limited number of tasks based on the exchanged information.
By "full interoperability" or "operational interoperability" between two entities we mean that the consumer entity is able to perform a full range of tasks based on the exchanged information.
Possible causes for inability to achieve operational interoperability between producer and consumer entities are:

- Quality mismatching;
- Data-incomplete mismatching.

Quality mismatching occurs when the quality profile associated with the exported information object does not meet the quality expectations of the consumer entity.
Data-incomplete mismatching occurs when the exported information object is lacking some useful information to enable the consumer entity to fully exploit the received information object.
In general, the meaningful exchange of information objects and therefore syntactic, structural and semantic interoperability is a necessary but not sufficient condition for achieving operational interoperability.
In fact, to achieve full operational interoperability between two entities the exchanged information must be complemented with some "descriptive" information, such as contextual, provenance/lineage, quality, security, privacy, etc. information which gives additional meaning. The descriptive information should be modelled by purpose-oriented descriptive data models /metadata models.
The use of purpose-oriented descriptive data models is of paramount importance to achieve operational interoperability.
The type of descriptive information to be provided by the producer entity depends very much on the requirements imposed by the consumer entity's tasks. For example, if the consumer entity wants to perform a data analysis task on the imported information then quality information is of paramount importance; without such information the task of data analysis cannot be performed.
Consequently, if the producer entity of an information object is willing to export/publish it, its possible uses by the potential consumer entities must be carefully taken into account and it must be endowed with appropriate descriptive information. Appropriate purpose-oriented information models /metadata models to describe the descriptive information must be chosen and used. If a multi-use of an information object is expected it could be necessary to associate different descriptive models/metadata models with it.

4. APPROACHES TO ACHIEVING INTEROPERABILITY PROBLEM

The main concept enabling the "meaningful" exchange of information objects is mediation. This concept has been used to cope with many dimensions of heterogeneity spanning data language syntaxes, information object models and semantics. The mediation concept is implemented by a mediator, which is a software device that supports a mediation schema capturing user requirements, and an intermediation function between this schema and the distributed information sources.
A key feature which characterizes a mediation process is the kind of intermediation function implemented by a mediator. There are four main functions:

- Mapping
- Matching
- Integration
- Consistency Checking.

Mapping refers to how information structures, properties, relationships are mapped from one representation scheme to another one, equivalent from the semantic point of view.
Matching refers to the action of verifying whether two strings/patterns match, or whether semantically heterogeneous data match.
Integration refers to the action of combining data residing at different sources, and providing the consumer entity with a unified view of these data.
Consistency checking refers to the action of checking the compatibility of logical relationships between functional / policy / organizational descriptions of two entities.
We can distinguish four main mediation scenarios:
Mediation of data structures: this permits data to be exchanged according to syntactic, structural and semantic matching. The functions of mapping, matching and integration are mainly adopted to implement this kind of mediation.
Mediation of functionalities: this make possible to overcome mismatching of functional descriptions of two entities that are expressed in terms of pre- and post-conditions. The functions of mapping, matching and consistency checking are mainly adopted to implement this kind of mediation.
Mediation of policies/business logics: this employs techniques to solve policy, business mismatches. The functions of mapping, matching and consistency checking are mainly adopted to implement this kind of mediation.
Mediation of protocols: this make possible to overcome behavioural mismatches among protocols run by interacting parties.
Automated mediation basically focuses on matching the producer entity information resources to the consumer entity needs. It relies on:

- Adequate modelling of structural, formatting, and encoding constraints of the producer entity information resources.
- Adequate modelling of the consumer entity needs
  - Domain-specific Ontologies;
  - Formally defined transfer and message exchange protocols.
- The definition of a matching relationship between the producer information resources and the consumer models.

There are several approaches to implementing the mediation process; of particular relevance are approaches based on standard data modelling formalisms, formal transfer protocols, and ontologies.

4.1 Ontology-based Mediation Approaches

Ontologies were initially developed by the Artificial Intelligence community to facilitate knowledge sharing and reuse. An ontology consists of a set of concepts, axioms, and relationships that describes a domain of interest.

Ontologies have been extensively used to support all the mediation functions, i.e. mapping, matching, integration, and consistency checking because they provide an explicit and machine-understandable conceptualization of a domain.
They have been used in one of the three following ways.
In the single ontology approach, all source schemas (producers entities schemas) are directly related to a shared global ontology that provides a uniform interface to the consumer entity.
In the multiple ontology approach, each source schema (producer entity' schema) is described by its own (local) ontology separately. Instead of using a common ontology, local ontologies are mapped to each other.
In the hybrid ontology approach, a combination of the two above approaches is used.
Ontologies provide a framework within which the semantic matching/mapping/integration/consistency checking processes can be carried out by identifying and purging semantic divergences. Semantic divergences occur where the semantic relationship between the ontology and the representation is not direct and straightforward

4.2 The Role of Standards in the Mediation Process

The role of formal models and standards in the development of mediation technologies is of paramount importance. In fact, automatic mediation requires the existence of formal models and standards for representing information objects, behaviour, functionality, policy, and protocols.

4.2.1 Information Modelling: Modelling represents basic technologies for modelling, organizing and exchanging information objects.
An information object is composed of a digital Data Object and the Descriptive Information which allows for the full interpretation of the data into meaningful information (see OAIS Reference Model (CCSDS, 2002)).
Several formal information models and languages have been defined and developed for representing, organizing and exchanging information objects (for example, RDF, XML, etc.).
Several discipline-specific standard models have been proposed and developed for representing discipline-specific descriptive information (discipline-specific metadata models) which greatly support the mediation process.
Logic-based and ontology-based models have been defined for representing behaviour, functionality, and policy (for example, OWL-S).
An important role in the mediation process is played by ontologies. Several domain-specific ontologies are being developed (e.g., CIDOC).

5. TYPES OF INTEROPERABILITY

Sometimes operational interoperability between two entities can be characterized by the type of actions the consumer entity is enabled to perform on the exchanged information. For example, if the consumer entity applies a preservation action on the exchanged information we characterize this type of interoperability as "temporal interoperability", as it guarantees access to the exchanged information over time.
Another type of operational interoperability occurs when the consumer entity is obliged to observe security, integrity, confidentiality / privacy, etc. constraints when performing tasks on the exchanged information object. In this case we characterize this type of interoperability as "secure interoperability".
When the consumer entity (usually a middleware component) is searching for a producer entity (another middleware component) that provides a given or complementary functionality, we characterize this type of interoperability as "functional interoperability".
When, in order to perform some tasks the consumer entity (usually an organization) needs to check the consistency of its behaviour / policies / business logics with those of a producer entity (another organization), then we characterize these types of interoperability as "behavioural interoperability", "organizational interoperability" and "business interoperability" respectively.
Therefore, temporal, secure, behavioural, functional, organizational, etc. are specializations of the operational interoperability.

6. CONCLUDING REMARKS

Achieving a full interoperability among Digital Libraries requires that all the Digital Library resources, i.e., content, user, functionality, and policy are interoperable. This means that different types of interoperability must be achieved, i.e. content interoperability, functional interoperability, policy interoperability, etc. and all of them concur to the achievement of a full Digital Library interoperability. This study has been conducted within DL.org, an EU 7th FP project (www.dlorg.eu).
We have emphasized that the use of purpose-oriented descriptive data models is of paramount importance to achieve operational interoperability.
Consequently, if the producer entity of an information object is willing to export / publish it, its possible uses by the potential consumer entities must be carefully taken into account and it must be endowed with appropriate descriptive information. Appropriate purpose-oriented information models / metadata models to describe the descriptive information must be chosen and used. If a multi-use of an information object is expected it could be necessary to associate different descriptive models/metadata models with it.

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E-PUBLISHING OPPORTUNITIES AND 3D REPOSITORIES FOR CULTURAL HERITAGE ON THE WEB: A STATE OF THE ART 2010

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KEY WORDS: 3D Web, Cultural 3D, e-Publishing, GeoWeb, Repository, Virtual Archaeology, Virtual Models, Virtual Heritage

ABSTRACT:

This short paper explores opportunities to publish Virtual Archaeology 3D models through the Web, addressing a scientific and academic audience. Features and standards of scientific (above all archaeological) 3D models are briefly addressed, with references to existing best-practice and prescriptive documents. Advances and issues related to 3D Web (3D contents on the Internet), such as Digital Right Management, are presented. The study focuses on the emerging category of 3D repositories in a state-of-the-art perspective, analyzing a certain number of general non-scientific examples to frame the phenomenon, and few representative systems targeted for Cultural Heritage virtual reconstructions.
This elaboration is part of a wider PhD research ongoing at Università di Bologna (PhD in History and Computing), dealing with communication and publishing of a case-study virtual reconstruction.

1. INTRODUCTION

Well-structured virtual models - provided that their realization is based on historically relevant sources and the creation process is documented - can be indeed considered as a spatially organized archive, allowing synoptic view and analysis of heterogeneous data (Forte, M., 2000; Borgatti, C., 2004).
In this sense, a great conceptual and practice innovation in the usage of virtual reconstructions is the introduction of links from the model to its documentary basis, in the form of multimedia datasets linked from database records or hypertexts: many application recently have made use of this useful feature, both in communication and in the previous analytical stages of research (Guidazzoli, A., 2007). By providing access to all collected and catalogued information, you enable greater accuracy in documentation and annotation of the model. Of course data need to be made uniform, in order to be able to treat them through a common interface.
As a consequence of the above, many international experiences prelude a new typology of scientific publication, considering 3D models not just as a new format for illustration or a special effect, but instead an integral part of the study.
So far, recognized formats for scientific ePublishing consisted mostly in traditional “textual” papers, possibly accompanied with multimedia documents such as video, images and links to external resources, or - at the most - web-pages collecting aggregations of linked items. As for distribution, web-magazines and web-press often display news through a proprietary portal and distribute contents to other portals, mashups and aggregators through RSS (e.g. Google News/Newspass for free/pay-news). Anyway, it’s a fact that non-textual communication is gaining momentum in web publishing, with the abandon of text as predominant content (one-way, verbal and linear communication) and the arise of images, video, icons and tags, (iconic-visual and non-linear language). This changes, together with diffusion of tactile and customizable interfaces, non-sequential texts, hyperlinks and content aggregators, in some way are realizing what Marshall McLuhan defined as a “post-literate age” due to arise of the new media (McLuhan, M., 1964).

With regard to Cultural Heritage (CH) field, in some Web-GIS and Web-VR-GIS applications text gives way to interactive maps or virtual environment as main interface to scientific contents, but this kind of initiative still require strong efforts in terms of investments, interdisciplinary équipe building, and IT expertise, thus they are most likely directed to promoting/communicating cultural contents in a didactic way, or to expositions or museum communication (see e.g. projects developed by CNR ITABC VH-Lab www.itabc.cnr.it/VHLab/Projects.htm).
On several outlets scholars can publish articles about their 3D models, illustrated by screenshots, renderings or screen-captured video fly-through, but only few services allow uploading of, and especially interaction with the models.
Some prescriptive documents have been developed in the meanwhile on correct cultural 3D, such as the London Charter (2005), aimed to set standards and best-practices for the realization and usage of 3d models for CH (www.londoncharter.org).
Reference is due to some recent initiatives for methodology and international coordination by the European Community, dealing with the use and value of 3D for CH, above all the NoE (Network of Excellence) Project EPOCH (www.epoch-net.org/), while previous projects such as MINERVA (www.minervaeurope.org/) had been focusing more on contents digitization and metadata indexing, paying little if any attention to 3d. Relevant best-practices have also been developed in other European projects and networks such as Athena (www.athenaeurope.org/) and Carare (www.carare.eu/), the latter bound to a wider project of metadata harvesting and indexing, Europeana (www.europeana.eu/).
Easy access to the web for 3d models directed to the scientific community is still widely under development. Nevertheless, it is probably a matter of few years before 3d models permanently acquire the status of a publication and sharing format for data - as a strong independent alternative to written text - as partially happened with images, audio tracks and videos in all user generated contents on the web.

2. 3D AND THE WEB

2.1 Online 3d contents

It is a fact that plug-ins and APIs concerning Web3D (any interactive 3D content on the Internet) are growing in number and adoption (see en.wikipeida.org/wiki/Web3d and related pages).

The two most active business fields related to this topic are Videogame and Geo-web (location-based information on the Web); MUVEs (Multi-User Virtual Environments, like World of Warcraft), Metaverses (Second Life and Open Simulator), 3D chat and communities (Active Worlds), have given strong economic and social impulse to the diffusion of Web-based interactive 3D management, while the huge market of Geo-RSS and GPS-based data, ruled by mapping services and software like Google Earth, caused development of strong 2D and 3D rendering engines.

In both sectors the creation of personalized collections of 3D objects and avatars by users is gaining momentum, along with exchange and sale of 3D models and textures.

After QTVR and VRML in the '90s, starting from the introduction of the ISO Standard X3D in 2004, Markup Language-based formats, often based on OpenGL Graphic Libraries, have become the standard. Among the most common formats we can count 3DMLW, 3DXML, COLLADA type formats (like Google's KML), Java 3D, O3D/WebGL and U3D. The latter, being natively supported in Adobe PDF documents, is probably the 3D format with the widest base of installed readers; PDF3D is indeed a useful tool for publication over the web, mainly for technical publications and engineering, since it only allows simple interaction, no access to the original data for editing; documents must be downloaded to be visualized (www.pdf3d.co.uk/gallery.php). Minor experiments come from the world of scientific research, like OSG4WEB, a plug-in for OSG- and OpenGL-based applications, developed by two major Italian research centers, Cineca and CNR (3d.cineca.it/storage/demo_vrome_ajax/osg4web.html, Calori, L., 2007). Finally, syntax for 3D effects and rendering has been recently included in languages supported by browsers, such as Adobe Flash. Among open formats, HTML5 includes some interesting features for 3D data rendering, and due to its extreme compatibility it is a promising option for achievement of complex interaction with some 3D data formats via browser.

However, hardware and software requirements still have great importance, and browsers do not support natively any standard plug-in for 3D visualization yet; anyway, remote rendering is probably going to be more and more adopted with the growth of broadband connections, while greater diffusion of desktop viewers and editors (like today Unity, Blender or Google SketchUp) shall be the condition for massive introduction of high-definition 3D data (currently not supported by broadband connections) for download and for desktop management and storage of information.

Huge repositories of geo-information currently have the power to dictate standards *de facto* and to lead the information market: the first truly massive spreading of 3D information layers through the Web probably started with the recent introduction of Google Earth APIs.

Open source communities also have large amount of geographical 3D data at their disposal, and could benefit from further evolution of open source tools for Web3D: for instance, OpenStreetMap is a user-created mapping website, originated from millions of GPS tracks. These data - released with open-source license - do have z-coordinate embedded, even if third dimension is not fully exploited or displayed at the moment (see en.wikipedia.org/wiki/Web3d and related pages).

2.2 3D data for research and communication

3D virtual reconstructions are getting more and more popular in CH, as in many other fields.

In the next few years 3D data are likely to be a common format for exchange and storage of complex data. This is primarily attested by increasing availability of hardware and software for handling graphical data, by the wide diffusion of broadband connection to the Web, by strong research investments in the videogame market, and by proliferation of geo-information service industries like GPS navigation, web sites, and mobile applications that make intensive usage of 3D graphics. Hardware, software and communication channels created for different domains can of course be used for scientific and historical purposes as well, through integration with scientific contents and methodologies.

While 3D reconstructions in the field of CH have widely proved their efficiency as communication tools - and are nowadays very common even in traditional mass media - some studies have also been facing the new opportunities for scientific visualization, analysis and organization of data (Forte, M., 2000.); Virtual Archaeology, offering the possibility of using a 3D model as interface for data visualization, gives way to an "*accessible, highly visual, and interactive means of representing research*" (Barceló, J. A., 2000).

Philological models, often rigorous rather than true-life, are often realized in humanities research as graphical counterpart of the traditional scholarly article. As did the original papers, they address an academic audience; besides contents and data related to reconstructed environments, a well-documented 3D model also conveys metadata (Information about characteristics, structure and origin of data) and paradata ("Information about human processes of understanding and interpretation of data objects." see www.londoncharter.org), who instead mainly concern the research process; thus it needs to be straightforward and clear on sources, authors, research documentation, reliability degree of elements, and allow high accessibility through the web.

Features of scientific models in optimal cases includes linking between elements and multimedia documentation, supports abstract data mapping (such as dimensions, morphology, spatial relation between elements), allows spatial simulation and testing about statics, visibility, lighting, capacity, use... and allows interactive handling, display and check of data rather than simple movement.

Transparency towards sources and the research process is a key issue in the creation of scientific virtual environments, as stated in the London Charter: "Sufficient information should be documented and disseminated to allow computer-based visualization methods and outcomes to be understood and evaluated in relation to the contexts and purposes for which they are deployed" (www.londoncharter.org).

Strategies to achieve transparency tested in past projects include: visibility of metadata, database connection, graphical coding of uncertainty, switch between alternative models, implementation of generative rules for Procedural Modeling (Müller, P., 2001; Müller, P., 2006; Frischer, B., 2008).

Specific needs are arising for cultural and scientific dissemination on the Web: Heritage is quickly adopting new communication strategies, inspired by social interactions that are often referring to computers and the Internet, such as networked services and virtual exhibitions. Open-software and services are widely used, while Web 2.0 has led to an interest towards open-contents, where users get actively engaged through community-building practices for "negotiation of meaning". Web portals and content aggregators are also a major asset, since they normally lead users' access to contents. Many European Projects have been drafting guidelines for the creation of quality portals for CH (MINERVA, MICHAEL) (www.michael-culture.eu/).

2.3 Licenses, sharing issues and DRM (*Digital Rights Management)*

Data sharing and dissemination in digital formats is often a mayor problem in CH, where researchers are often dealing with copyrighted material, complex IPR (*Intellectual Property Right*) status, and a variety of involved subjects: public administrations, universities, museums often share rights pertaining to cultural objects or contexts, with the consequence of neither of them having data at its disposal.
Direct access to the objects and sites, moreover, is different from access to derivative contents and data, that are produced through digitization and will constitute the actual digital identity of the original object. Compound services - like content aggregators - also require access to data, adding further complexity. Intellectual property rights in this case should be reasonably managed entirely through digital procedures, and this also creates an access barrier for many users.
Mainly for this reasons, sectors where syndication (separate indexing of metadata) is possible - OPAC and digital libraries - have been developing quicker digitalization and web distribution (see www.minervaeurope.org/publications/globalreport.htm).
However, some new tools have been developed for Digital Rights Management (Ronchi, A., 2009, pp. 287-312.), though often accompanied with an unprotected preview of part of the contents:

- *Access control systems* (access to different levels of contents is managed through password protection or requiring payment);
- *Copy protection systems* (information about the extent of copying permitted, if any, is embedded in the file code, in the hosting device for off-line contents, or ensured by the web access path);
- Full enabled *Intellectual Property Rights management system* (allow very granular control over contents, including commercially relevant information, and creation of sophisticated usage models);
  IPR is actively protected using methods such as:
- *Watermarking or digital/invisible watermarking*: insertion of information (number, text, image...) into multimedia data or their preview version through slight modification of the data; visible watermarking is particularly used for imagery and video, while invisible watermarking applies to the code; both must be easily identified even in partial copies, or in reproductions made on different media;
- *Trusted systems*: this kind of data protection systems require interconnected devices to adhere a *code of conduct* in order to allow visualization while protecting data;
- *Ecryption*: suitable for any type of data, encryption consists in separating metadata or descriptive data (available for preview) and encrypted datasets (available on external support, not available at all or released under *pay-per-view* conditions);
- *Hard keys*, or more recently *Soft keys*: often combining software components with internet connection, this method is widely used for registration of applications, services or activation of access credit;

Of course great effort is being spent in the establishment of well-structured worldwide legal tools like the range of Creative Commons licenses (creativecommons.org/).
Review processes and quality filtering systems also have a great importance: the development of easy-to-access ePublishing opportunities entails a weakening of traditional publishing institutions as scientific warranty for contents, and this implies growing difficulties in filtering and locating those high valued works that will merge into common knowledge of the scientific community.
EPublishing institutions shall therefore ensure an effective and participated review system, and maintenance of the traditional references to authors, individual contribution to complex projects, bibliography, notes, and citation from reliable sources.
About the quality issue, suggestions were made in recent past about the need of a quality control institution in Virtual Archeology (Frischer, B., 2002.), eventually leading to some pioneer applications and to further achievement in theory (www.londoncharter.org).

3. REPOSITORY SYSTEMS FOR CULTURAL 3D

3.1 Workshops and best-practices on cultural 3D

Many projects and workshops dealing with digitization and web contents for CH have been coping with the issue of 3D contents and the Web.
BRICKS European Integrated Project (Building Resources for Integrated Cultural Knowledge Services, www.brickscommunity.org/), in close collaboration with MINERVA (Ministerial Network for Valorizing Activities in Digitization), aimed to constitute a new generation of 'digital libraries', covering digital museums, digital archives and other kinds of digital memory systems: for the first time in this kind of project, 3D models were taken into account.
A dedicated group worked on methodological aspects of Cultural 3D, giving rise to the London Charter project in 2005.
In the following years interesting advances came mainly from coordination projects about semantic interpretation for the Web and metadata recording into Digital Libraries: extracting data relative to digital objects is the first step to catalogue, index and retrieval contents in large databases. Virtual resources and 3D reconstructions are indexed according to Dublin Core standards (not physically gathered) in the European MICHAEL Web Portal, a spin-off product of MINERVA.
Recent research on the introduction of semantic in 3D modeling can be found in FOCUS K3D (www.focusk3d.eu/), AIM@SHAPE (www.aimatshape.net/), and CARARE Projects. The latter is a best-practice network aimed at adding 3D and Virtual Reality contents to EUROPEANA, an European portal for access to cultural digital collections.
Great theoretical advance and some important technical achievements, finally, came from EPOCH Network of Excellence: for instance Arc3D Web Service - a system for remote automatic photo-modeling of cultural artifacts and environments, Mini-Dome, a portable digitization system for small artifacts, and MeshLab, an editor for processing point clouds into meshes, most of them released under open source license (MeshLab) or made available for free for research purposes. In addition, EPOCH Network developed InMan (Interpretation Management), a methodology and framework for the creation and publication of 4D scenes, based on

implementation of the London Charter; the tool assists users in the creation of a source database and of the documented 4D scene, that can be made available online through hyperlink on a visualization page, stored into a repository and shared or discussed through social media such as a specific forum.

3.2 Repositories as work and presentation tools

In the meanwhile, in the world of non-scientific 3D Web a new category of resource is rapidly spreading: 3d web repositories. With the increased availability of low cost software and hardware equipment for graphic visualization, the growth of broadband connection and the proliferation of 3D and geo-information, the creation of online galleries of user generated 3D items for various purposes has become very common.
Some examples are:

- **Personal objects** collections pertaining to users of metaverses, 3D chat and MUVEs (often supplied by a dedicated market, as in Second Life);
- **3D artists works** and collaborative collections (Blender artists e2-productions.com/repository/index.php, www.sharecg.com/, Open Simulator artists opensimulator.org/wiki/Artist_Home);
- **Highly specialized repositories** (Proteins models, University of Basel swissmodel.expasy.org/repository/);
- **Object, material and texture libraries** to be used for professional 3D modeling or for videogame design (www.archidom.net/; archive3d.net/, www.3dmodel.eu/, www.exchange3d.com/...);
- Collaborative projects for massive **thematic reconstruction** (Virtual Cities, interactive visualization of massive urban 3D environments vcity.c-s.fr/EN/index.html);
- 3D galleries as a **portfolio** for institutions working in the field of Virtual Reality or Computer Graphics (VCLab of ISTI-CNR www.vihap3d.org/news.html; vcg.isti.cnr.it/downloads/3dgallery/vclgallery.htm);
- **Web-museum exhibitions or educational resources** (MUVI Project muvi.cineca.it/ or Museo Virtuale della Certosa www.certosadibologna.it/, developed by VisIT Lab, Cineca);
- And of course, **Google Sketch Up Warehouse** for online storage of 3D models realized by users for Google Earth engine (sketchup.google.com/3dwarehouse/);

Access is usually divided in two stages: 1) simple preview of metadata, additional contents and screenshots from the models, and 2) interactive visualization of model, after installing a plug-in component and/or authenticating.
As for implementation, there are a bunch of systems - some of them open-source (Eprints, Fedora or DSpace) for management of online objects and contents repositories; links and documentation about these tools can be easily found on the Web (Doerr, M., 2009; see www.rsp.ac.uk/software/surveyresults, www.manageability.org/blog/stuff/open-source-document-repository, java-source.net/open-source/content-managment-systems,).
Actually 3D repositories could turn out to be great tool for collection, dissemination and publishing of scientific 3D, allowing good control over data handling, account management, and taking advantage of growing accessibility of 3D contents through the Internet. A quick examination of some existing cases may explain possible applications and highlight issues and perspectives.

3.3 CH Repository systems: a comparison

AIM@SHAPE is a NoE European Project, financed by the EU's Sixth Framework Programme in the Action Line on Semantic-based knowledge systems. This project focuses strongly on Web Semantic, interpretation, indexing and retrieval of digital documents, and particularly 3D objects. More than being a sharing and publishing platform, Aim@Shape shape repository is a benchmark gallery for best-practices in creating efficient semantic and metadata from 3D shapes.

Name: AIM@SHAPE. Advanced and Innovative Models And Tools for the development of Semantic-based systems for Handling, Acquiring, and Processing knowledge Embedded in multidimensional digital objects
Year(s): 2004-2007
Project Coordination: Bianca Falcidieno, IMATI-CNR, Dept. of Genova
Web Link: shapes.aim-at-shape.net/
Involved Institutions: 14 research centers, 91 partners www.aimatshape.net/project/consortium/
Funding: EU's Sixth Framework Programme
Description: The mission of AIM@SHAPE is to facilitate development of new methodologies for modeling and processing the knowledge related to digital shapes. Repositories were created as common work platforms, for publications, software tools, metadata and 3D shapes (dsw.aimatshape.net/).
Shape Repository provides a collection of test cases and benchmarks, in order to enable efficient prototyping as well as practical evaluation on real-world and large-scale shape models. Shape models in the repository are categorized according to the Shape Common Ontology developed within the project. Each shape model is accompanied by ontology-driven metadata. High-quality models are acquired, and tools from the Tool Repository are integrated to automatically extract metadata for certain shape categories. Download of models for some shape categories in **multi-resolution format** is allowed at the desired LoD (Level of Detail).
A category tree, a Geometric and a Semantic search engine have been implemented, and models can be grouped according to topic, author, hierarchy and so on. Different versions (e.g. different re-meshing) of the same shape can be made available.
Supported Formats: Various, from geometric representation (mesh, parametric models, point clouds...) to raster data and motion capture. Shape Repository collects PLY, OFF, VRML, OBJ, IGES, STEP and much more format, with different interaction levels.
Access Model: Users can **preview images and metadata** related to models shapes.aim-at-shape.net/viewmodels.php. Manifold Surface meshes can be **viewed and simplified selectively online**, and the result of the simplification can then be downloaded directly.
Owners define specific licenses for download of their models, stating that model shall be accompanied by its metadata file in future use. In addition, a General License governs the use of all models acquired from the repository. A few models are available only to project members through their logins.
Contribution Model: Content providers are researchers from participating institutions. Most of the high quality models have been acquired exclusively for the repository through scanning sessions. Hosting, maintenance and development of the Repository is responsibility of partner MPII.

3D-COFORM is a Consortium, founded by former partners of the NoE European Project EPOCH, aimed at developing and implementing software and hardware components for broad-based digitization and 3D data handling. Below ARC3D Web Service, MeshLab and other EPOCH tools for scanning and texturing, 3D-COFORM participated in the creation of City Engine, a software for procedural modeling, and is currently developing further advanced components for web navigation of Cultural 3D models. Models are collected with strong attention to semantic and metadata. They mostly consist in meshes from laser-scanning or in results of the open-source pipeline promoted by EPOCH: Arc3D automatic photo-modeling Web Service and further processing with another open source tool, MeshLab, developed by ISTI-CNR. The repository is to be considered a working tool, and it also hosts raw data, e.g. unrefined data from SSC Engine or Dome scanning systems.

Name: 3D-COFORM. Making 3D documentation an everyday choice for the Cultural Heritage sector
Year(s): 2008-2012
Project Coordination: David Arnold, University of Brighton, UK
Web Link: www.3d-coform.eu/index.php, www.3d-coform.eu/; Documentation: 3d-coform.eu/index.php/downloads/cat_view/34-public-deliverables
Involved Institutions: 19 partners www.3d-coform.eu/index.php/partner
Funding: Funded by EU's Seventh Framework Programme: 8M €
Description: The aim of 3D-COFORM is to establish 3D documentation as an "affordable, practical and effective mechanism for long term documentation of tangible CH"; it addresses all aspects of 3D-capture, 3D-processing, the semantics of shape, material properties, metadata and provenance, integration with other sources (textual and other media); search, research and dissemination to the public and professional. 3D-COFORM is based on CIDOC-CRM ontology for the management of semantic. Metadata, including provenance, sources, links and cultural-historical documentation are supported.
Protection of data handled through MeshLab is performed via digital watermarking, while in the scanning pipeline location and authentication are automatically acquired and encrypted.
VSL Scene Manager is a tool for visualization, allowing LoD handling, contents layering, visualization and saving of COLLADA-L. Rendering is performed server-side and requires the installation of a plug-in (IVB, Integrated Viewer Browser).
Supported Formats: Scanning tools developed inside EPOCH have preset formats (like OpenEXR point cloud files and XML metadata for SSC Engine). MeshLab can export into the most common 3D formats. Standard encoding for mesh files is COLLADA-L. The repository supports VSL compatible formats, triangular meshes in OBJ, COLLADA and PLY and PTX point cloud format. Various kinds of multimedia data (images, video, texts) are supported. PDF documents, CityEngine models, SiteExplorer scenes, PhotoCloud datasets, GIS data and more will be handled through external components.
Access Model: Museums and other institutions reserving rights over contents can set access conditions; usually access is based on user-authentication.
Contribution Model: Empowering user generated contents is among aims of the project. So far contents have been providen by participating institutions and EPOCH tools users.
CY-ARCH is a scientific non-profit entity involving many partners; it is strictly focused on models acquired from laser-scanning with the purpose of preserving and documenting at-risk archaeological sites. Historical and context information are displayed besides the 3D models into Projects, each one being dedicated to a site of interest. Little less than 50 Projects are active.

Name: CY-ARK. Digitally Preserving and Sharing the World's Cultural Heritage
Year(s): From 2001
Project Coordination: Founders: Ben and Barbara Kacyra
Web Link: archive.cyark.org/
Involved Institutions: A huge partners board is this project's main asset: archive.cyark.org/partners
Funding: Grant from the Kacyra Family Foundation, corporate sponsors, partners, donations and volunteering.
Description: Purpose for data acquisition is usually driven by either research needs or site management, conservation, restoration and documentation. Metadata associated to point clouds consist mainly in geo-referencing, while more information are attached as external documentation. Maps can have a GIS-like layer of icons, pointing to external resources, and a similar feature is under developement for 3D models.
Supported Formats: ASCII point cloud formats like PTX, PTS, XYZ, some proprietary formats (POD, IMP), the most common mesh formats (3DS, OBJ, DAE). The viewer, (developed internally, requires plug-in) will support PTS and 3DS and allows interactive visualization and extrapolation of sections, plans, and measurements from point clouds.
Access Model: Users are required to login in order to facilitate identification and IPR protection, with no fee charging; Contents are organized into Projects (Archaeological Sites), and shall include different datasets, like Maps, Elevations, Photographs, Panoramas, 3D Point Clouds, Shots and Videos. Preview of photos and of low-resolution screenshots of the models is provided. Access to contents is dependent on individual agreements with authorities, being mainly limited by Creative Commons License.
Contribution Model: Acquisitions - most of them high-definition - are encouraged and financed by partners to populate the repository, and released for study purposes. The staff also welcomes data from independent scanning, whose accuracy and completeness will be evaluated and described in the attached documentation.

SAVE Project, born consequently to the realization of the Rome Reborn reconstruction project (Frischer, B., 2008), is particularly interesting for three reasons:

- technical infrastructure (3D Web Service Project by ENEA) uses powerful graphic clusters for Remote Rendering (fully interactive visualization online);
- the declared aim of the project is to create a specialized journal (distribution agreement with a US publisher is scheduled);
- it allows use of models as social environments, populated with avatars and equipped with IM and VOIP services, to facilitate educational use;

Name: SAVE - 3DWS. Saving and Archiving Virtual Environments (IATH); technical infrastructure: 3D Web Service Project (ENEA)
Year(s): From 2009

Project Coordination: Bernard Frischer (IATH Virginia University)
Web Link: www3.iath.virginia.edu/save/
Involved Institutions: Virtual World Heritage Laboratory, Virginia University (US)
ENEA Research Center, Bologna and Napoli, Italy
Funding: Support from US NSN (National Science Foundation)
Description: SAVE project has been created with the goals of offering the creators of scientific 3D models of CH sites the opportunity to have an outlet for the peer-reviewed publication of their work over the Internet; to ensure that their work is preserved for future generations; and to protect the intellectual property rights of the creators as well as the integrity of the models themselves. It aims to be the world's first on-line, peer-reviewed journal in which scholars can publish 3d digital models of the world's cultural CH sites and monuments.
www3.iath.virginia.edu/save/
Supported Formats: For the moment high resolution files are required in 3DStudio Max or Maya format; a simplified version can be published in Kmz (for visualization by users on Google Earth); a third possibility is to upload a simplified version of the model, defined "collaborative", enhanced with avatars, VOIP and instant messages service, in order to facilitate use n teaching and research.
Access Model: Registered users can access interactively via **remote 3D** to high-definition models, (but a Java applet installation is required); the database is queried through free search keywords; preview for not registered users includes metadata and still screenshots;
Contribution Model: Content providers are registered users and will pass through technical and subject review; post-publication peer-review will be made possible by a blog Comment section; intellectual property related to the models is protected through watermark; a related monograph, **metadata and** underlying **documentation** can be associated to the model; also studies related to 3D CH models will be published through SAVE;

4. CONCLUSIONS

Scientific metadata repositories and archives don't usually allow 3d data handling, though convergence is near to come (e.g. Carare project for Europeana). On the other hand, 3D model repositories often comply with aesthetic purposes (e.g. Blender Artists repository e2-productions.com/repository/index.php) or consist in specialized services (such as protein models collected by University of Basel swissmodel.expasy.org/repository/).
Few repositories have been developed specifically for CH, offering wider possibilities both for scientific dissemination ad for communication to the public.
A remarkable feature of some of the analyzed services is the possibility to connect 3d data to other types of data (sources, metadata, paradata, multimedia): this is what basically differentiate scientific content networks from generic 3D repositories.
Even though these networks were born inside academic research environments or small user group and deal with protected contents, most of them are oriented toward a model of collective management of knowledge and shared development. As stated in an important essay by E. S. Raymond on software engineering methods, we need to switch from a cathedral-like knowledge model, based on small groups with exclusive access to data, to a new bazaar-like model (Raymond, E.S., 1997).
Sharing and co-operation through the Web are necessary backbones for the adoption of the new model, where quality and sustainability - often also in an economic sense - are assured by the consolidation of a wide user community. Furthermore, the ability to share contents with a large audience is usually an incentive for users to create more and better contents (Abate, D., In press).
Open source perspective needs to be spread into the world of CH, to avoid the huge loss of time, energies, and data obsolescence, caused by the lack of cooperation and the refuse to share information with other institutions.
Among advantages in the adoption of an open bazaar-like knowledge and research model there are costs drop, sustainability, better digital preservation, easier resource sharing and reuse of contents, major investment in human resources.

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DISCOVERY AND USE OF ART IMAGES ON THE WEB: AN OVERVIEW

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KEY WORDS: Art Images, Repositories, Image Retrieval, Content-Based Indexing, User Expectations, Interoperability, Europeana

ABSTRACT:

This paper provides an overview of the area of resource discovery in the case of art images. Digitized art images are an important part of the online cultural heritage. Digitization and online accessibility were mainly materials focused on by libraries, museums, archives and audio-visual archives in the last decade. However, digitised art images as well as digitally-born art provide a major challenge for resource discovery and use. Better results in resource discovery could be achieved through methods combining queries executed on metadata with image retrieval methods. The paper gives an insight into the evolution of designated repositories for digital art, and then briefly presents some of the basic methods for intelligent resource discovery in this domain. Finally it looks at directions for further development within the digital repositories of art, which would enrich even more the user experiences.

1. INTRODUCTION

A key characteristic of visual arts' objects is that they are created by a cognitive process. The artwork is not merely an objective presentation, but also communicates one or more subjective messages "delivered" from the creator to the observer. Every touch to the artwork helps to build bridges between cultures and times. As suggested in (Chen et al, 2005) "research on significant cultural and historical materials is important not only for preserving them but for preserving an interest in and respect for them".

Since its first publication in 1962 Janson's History of Art (Janson, 2004) is one of the most valuable sources of information spanning the spectrum of Western art history from the Stone Age to the 20th century. It became a prominent introduction to art for children and a reference tool for adults trying to recall the identity of some familiar images. The colourful design and numerous illustrations of exceptional quality are far from being a means of providing dry information; they also contribute to experience a deep emotional fulfilment.

But now online search engines have whetted web surfers' appetites for context and information, there are a host of digital databases and repositories offering easy access to digital items, presenting the colourfulness of art history as well as to connected metadata, giving all additional information from pure technical details, connected with the way of creating the artefacts, to deep personal details from the lives of the creators, which help the observers to understand input message in the masterpieces.

In Section 2 we look into the evolution of such systems and provide some examples. Then in Section 3 we focus on the specifics of access to art images. In section 4 we outline some of the influences of the Web on the organization of art resources in digital form. Finally, we provide some conclusions on the issues which are most challenging in this domain.

2. DIGITAL REPOSITORIES OF ARTWORKS

The digital repositories of cultural heritage objects can employ similar techniques as generic ones in order to provide standard functionality for searching objects. Cultural heritage objects are rich in content describing events, monuments, places, people; they are distributed across different locations. The users can formulate queries using different modalities such as free text, similarity matching, or metadata; one important current trend is the use of linked data (Gradmann, 2010). The specifics of observed objects profile some additional tasks, which are interesting to be considered. In the area of art paintings retrieval the sensitive, semantic and aesthetic gaps are a prevailing problem.

In 2004 David Mattison, named as a master of the online archive universe, published a series of lectures in the Searcher magazine focusing on the state-of-the-art of available Web resources and image databases, current techniques for image retrieval, and finally mentioning national collections that document the art history of Western civilization from medieval times to the 19th century (Mattison, 2004). The creators of this set of image databases, art collections and guides usually are academic, librarian, commercial, and private art museums and galleries, amateur and professional art historians, artist sites, commercial image agencies, auction houses (usually on a temporary basis), etc.

Several different applications in the field of Fine Arts have led to specialized digital image processing developments. During the years numerous successful projects in the field of processing very large high quality colour images had been funded by Esprit, Impact, Raphael, and IST programs of the European Commission. They provide the most conventional image processing for the museum, such as geometric correction, registration, mosaicing, etc. (Maitre et al, 2001). The European Union has funded a number of digital culture research and development initiatives.

Some of the projects, such as *Vasari* (1989-1992) and *Marc* (1995-1996), are focused on digital acquisition, storage and

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handling of colorimetric high-definition images of paintings (up to 2GB per image) for different galleries and museums in Western Europe. The *Crisatel* project (2001-2004) developed equipment for the direct fast capture of paintings, with a new ultra-high definition multi-spectral scanner in order to make spectrometric analysis of varnish layers to allow the effect of an aged varnish to be subtracted from an image of a painting. The project *FingArtPrint* (2005-2008) aimed to make combinations of 3D surface scanning and multispectral imaging in order to create a unique data record of the object which can be compared to check its authenticity.

Several other projects and initiatives pursued the creation and population of art image repositories. One of the first projects in this direction was *NARCISSE* (1990-1992), which has created a very high digitized image bank, supervised by a multilingual text database. The objective of the project *Artiste* (2000-2002) was to develop and to prove the value of an integrated art analysis and navigation environment aimed at supporting the work of professional users in the fine arts. The environment has exploited advanced image content analysis techniques, distributed hyperlink-based navigation methods, and object relational database technologies using existing metadata standards and indexing schemes.

In recent years several projects and initiatives focused on the harmonization of activities carried out in digitization of cultural and scientific content for creating federated platforms for storage of and access to cultural heritage. Such project is *MINERVA+*, sponsored by 6FP, which intends to enlarge the existing thematic network of European Ministries in this direction. Since 2005 the Netherlands Organization for Scientific Research supports the research program *CATCH* (Continuous Access to Cultural Heritage) that finances teams which concentrate on improving the cross-fertilization between scientific research and cultural heritage. In the light of transferability and interoperability, the research teams execute their research at the heritage institutions.

The latest and biggest project in this domain is *Europeana* (http://www.europeana.eu/portal/), funded by the European Commission and the member states. The idea of *Europeana* was born in 2005, when the European Commission announced its strategy to promote and support the creation of a European digital library as a strategic goal within the European Information Society i2010 Initiative, which intends to foster growth and jobs in the information society and media industries. The European Commission's goal for *Europeana* is to make European information resources more available in an online environment. It will build on Europe's rich heritage, combining multicultural and multilingual environments with technological advances and new business models. Currently over 10 million digital items are available through the portal.

Some of very successful worldwide digital repositories are created independently as a result of collaboration between different stakeholders, most often state or public institutions; or by supporting concrete companies. Usually the funding for establishing and supporting such initiatives is received by donations; by sparing out of the budgets of the institutions; or by allocating funds from the profit of the companies gained with other activities (for instance Artchive is supported by art.com, which is a company that sells digital posters of fine art and decor items).

Here we will mention some examples of such repositories.

Artcyclopedia (http://www.artcyclopedia.com/) is an online database of museum-quality fine art founded by Canadian John Malyon. The site is the leading guide to museum-quality fine on the Internet. The Artcyclopedia is a form of Internet search engine and deals with art that can be viewed online, and indexes 2 600 art sites with links to around 140 000 artworks by 9 000 renowned artists.

Artchive (http://www.artchive.com/) is a virtual art gallery website, coordinated by Mark Harden. The site is a leading example of an independently established collection of high-quality pictures, which are important in the history of art. Works include art from various periods, such as Abstract Expressionism, Baroque, Impressionism, Renaissance, Romanticism, Rococo, Surrealism and more.

OCAIW (Orazio Centaro's Art Images on the Web) (http://www.ocaiw.com/) is an educational and non-profit site for art-lovers, teachers, students, artists and collectors. The catalogue consists of information about painters, sculptors, architects and photographers. Every section of the catalogue includes a listing of the greatest artists in Art History. The authors' index lists about 1 500 artists from medieval times to the present.

WebMuseum (http://www.ibiblio.org/wm/) is one of the earliest examples of a virtual museum. Starting in 1994 as WebLouvre, now many mirror sites are established throughout the world. It provides an excellent archival and educational resource of good quality art images and information. WebMuseum is part of one of the largest "collections of collections" on the Internet *ibiblio* (http://www.ibiblio.org/), a conservancy of freely available information including software, music, literature, art, history, science, politics, and cultural studies.

Web Gallery of Art (http://www.wga.hu/) is a virtual museum and searchable database of European painting and sculpture of the Romanesque, Gothic, Renaissance, Baroque, Neoclassicism, Romanticism periods (1000-1850), currently containing over 23 000 reproductions. Picture commentaries, artist biographies as well as guided tours, contemporary music, catalogues, free postcards and other services are available.

Backtoclassics (http://www.Backtoclassics.com/) is a new virtual art gallery (since 2009) created by the Italian division of Microsystems MS Lab, which provides an insight into the creations of artists past and present, where paintings are classified not only by movements and artists, but also thematically (for instance Rembrandts' paintings are grouped into the following series: Portraits; Biblical Themes; Various Paintings; Self-Portraits; Etchings; Drawings; Landscapes).

Olga's Gallery (http://www.abcgallery.com/) is one of the largest online painting museums containing works and biographies of most of the world's best known artists. Olga's Gallery was founded in 1999 as a fine art-themed website under the domain name abcgallery.com (abc is part of the motto of the site "The abc of art") by the sisters-in-law Olga and Helen. Now Olga's Gallery contains over 12 000 works of art by more than 300 painters and receives over 30 000 visitors and 1 000 000 page views daily. Artists can be searched by name, country or genre, which you will find most useful. The site also includes brief biographies of significant artists with excellent links to more specified sites converting it into an indispensable research source for young students.

Many museums currently offer online galleries supplying access to their collections. The search engines of some of them are using only the metadata using categories such as artist, title of work, subject, chronology and reference number (for instance http://www.museodelprado.es/). In other sites attempts to implement content-based image retrieval (CBIR) techniques during the search process are included (such as http://www.hermitagemuseum.org); these techniques are presented in section 3.2.

3. THE INTELLECTUAL WEB ACCESS TO IMAGES

The digital repositories of art images are created to facilitate resource discovery and provide access to numerous digital objects. In this section we will outline the basic methods which are currently used for this domain.
As mentioned in Chen and Rasmussen (1999), the newly available image capture techniques, inexpensive storage, and widely available dissemination methods have made digital images a convenient and easily available information format. This increased availability of images is accompanied by a need for solutions to the problems in indexing and retrieval. Traditional concept-based indexing uses controlled vocabulary or natural language to express what an image is or what it is about. Newly developed content-based techniques rely on a pixel-level interpretation of the data content of the image. The upper stage of indexing techniques – concept-based indexing is based on mixing of simple text-based and content-based tools taking into account additional information for interconnections between perceived information from the main player of this process – "the user".

3.1 Text-based indexing

This trend of work has been analysed in numerous projects. The advancement in the processes of ordering and classifying the meta-information is very significant, although text-based indexing methods are vastly manual, effort- and time-consuming. Let's only mention the richness of gathered and structured information in Getty vocabularies[1]. The vocabularies in this program are:

- The *Art and Architecture Thesaurus – AAT* (containing around 34 000 concepts including 131 000 terms, descriptions, bibliographic citations, and other information relating to fine art, architecture, decorative arts, archival materials and material culture),
- The *Union List of Artist Names – ULAN* (containing around 127,000 records including 375,000 names and biographical and bibliographic information about artists and architects, including a wealth of variant names, pseudonyms and language variants),
- The Getty *Thesaurus of Geographic Names – TGN* (containing around 895 000 records including around 1 115 000 names, place types, coordinates and descriptive notes focusing on places important for the study of art and architecture), and
- The *Cultural Objects Name Authority – CONA* (forthcoming in 2011; it will include authority records for cultural works, featuring architecture and movable works such as paintings, sculpture, prints, drawings, manuscripts, photographs, ceramics, textiles, furniture, and other visual media such as frescoes and architectural sculpture, performance art, archaeological artefacts, and various functional objects that are from the realm of material culture and of the type collected by museums).

The use of these ontological structures in image retrieval processing leads to a decreasing metadata amount and expands the research scope utilising defined interconnections between concepts.
In addition, a number of text-based indexing initiatives deal with the development of metadata schemas and structures to classify image information. We could mention for example *Dublin Core* (Dublin Core, 1999), which is used primarily for retrieving resources on the web, *VRA Core* (VRA, 2002), which has elements to describe both an original work of art and its surrogate, *CIDOC CRM* (CIDOC, 2006) that gives conceptual reference model intended to facilitate the integration, mediation and interchange of heterogeneous cultural heritage information.

3.2 Content-based indexing

Content-based image retrieval (CBIR) is an area where knowledge is being extracted from the image content of the digital picture archives. Starting with searching by simple visual similarity between given picture or sketch, current CBIR systems pretend to be promising assistants in the processes of searching content by visual as well as by semantic similarities and became a helpful alternative for image retrieval.
CBIR, as we see it today, is any technology that helps to organize digital image archives by their visual content. By this definition, anything ranging from an image similarity function to a robust image annotation engine falls into the range of CBIR. This characterization of CBIR as a field of study places it at a unique juncture within the scientific community. While we witness continuing effort in solving the fundamental problem of robust image understanding, we also see people from different fields such as, computer vision, machine learning, information retrieval, human-computer interaction, database systems, Web and data mining, information theory, statistics, and psychology contributing and becoming part of the CBIR community (Wang et al, 2006). Image analysis processing techniques provide a powerful means of extracting useful information from content. The efforts are directed towards the use of extracted low level information such as colour and texture, or primitives, such as salient points, corners and shapes, and higher-level information, such as objects, scene content, subject description, for constructing upper levels of understanding the meaning of the images under different aspects. Content annotation based on pixels can be used to perform search operations from objective measures and descriptors of the visual content. Effective descriptors that agree with human perception and feeling are required, but also with particular attention paid to the computer science "semantics" of images and scenes among other things. Thomas Hurtut presents a detailed survey of the literature of 2D artworks analysis techniques (Hurtut, 2010). Following a content-based taxonomy, the transition from low-level features to high-level layers of concepts is discussed. He also suggests several kinds of abstraction, which are specific to art images and distinct from the generic semantic challenge.

3.3 The User Needs and Expectations

The main focus in the creation of digital art resources has to be user-centred rather than system-centred since most of the issues around this content are related to making it accessible and usable for the real users (Dobreva and Chowdhury, 2010). Leo Konstantelos examined in his doctoral dissertation the needs for scholarly information retrieval within the context of Digital Art in Digital Libraries (Konstantelos, 2009).
In the image retrieval systems, an important parameter to measure user-system interaction level is the complexity of queries supported by the system. The queries can use different modalities such as: directly filling the values of the desired features; giving the image or sketch as example; keywords or free-text, and their combination.
Exploring user needs and behaviour is a basic and important phase of system development. Currently users are mostly involved in usability studies when a set of digital resources has already been created and is being tested (for an overview on usability evaluation methods in the library domain see (George,

[1] http://www.getty.edu/research/conducting_research/vocabularies/

2008)). It would be really helpful to involve users on early stages of design and planning the functionality of the product which is being developed.
Amongst the various methods for involvement users in the evaluation of a product, relevance feedback is a key one in image retrieval, because it defines the goals and the means to achieve them. It provides a compromise between a fully automated, unsupervised system and one based on subjective user needs. Relevance feedback is a query modification technique which attempts to capture the user's precise needs through iterative feedback and query refinement. It can be thought of as an alternative search paradigm to other paradigms such as keyword-based search. In the absence of a reliable framework for modelling high-level image semantics and subjectivity of perception, the user's feedback provides a way to learn case-specific query semantics. A comprehensive review can be found in (Zhou and Huang, 2003) and (Crucianu et al, 2004). The goal in relevance feedback is: given the rather small amount of interaction with the user during a session, it is important to use all the available information to improve the retrieval results. Based on the user´s relevant feedback, learning-based approaches are typically used to appropriately modify the feature set or similarity measure. In practice, learning instances are few. This circumstance has generated interest in novel machine-learning techniques to solve problems such as *one-class* learning, *active* learning, and *manifold* learning. Usually, classical relevance feedback consists of multiple rounds, which leads to losing the patience in the user. Recent developments are directed to find techniques for minimizing the rounds, keeping the history of earlier user logs in the system and on this basis creating user profiles.
The increasing number of digital repositories on the Web fosters research into consumer needs and expectations about the content and services provided by the repositories. Despite the increasing number of studies on consumer expectations and perceptions, yet these studies are not sufficiently advanced to offer easily applicable models and recommendations. For example, a recent study noted that "the focus of research on digital libraries is on technical issues (e.g. information search methods, software architectures, etc.)" rather than on consumers (Khoo et al, 2009).
The evaluation of digital repositories in terms of its efficiency and ease of use is not specifically aimed at understanding users' attitudes in dept (Europeana, 2009). Recently, studies are focused on information literacy and behaviour of individual groups, e.g. young people, or the "Google generation" (Google, 2008).

4. THE WEB SPACE

4.1 The interoperability

In the web space plenty of additional issues arise connected with creating a framework that includes the image, the delivery system and the users (Jörgensen, 2001). Numerous repositories are already available and many systems for reaching the content are implemented and used in the practice.
In current years, the problems of semantic, syntactic and profile interoperability and constructing reference layers are very topical (DCMI, 2009); additional areas to explore are linked data which allow to contextualise objects in the cultural heritage domain.
Today interoperability is considered a key-step to move from isolated digital repositories towards a common information space that allow users to browse through different resources within a single integrated environment (Vullo et al, 2010).
Some problems are connected with the scientific study and development of innovative technological solutions for assembling multimedia digital libraries for collaborative use in the context of cultural heritage, supporting their semantic interoperability and developing new services for dynamic aggregation of their resources, improvement of access, personification, intelligent curation of content, as well as content protection and ensuring intellectual property rights.
An example for addressing the interoperability challenge exhaustively is the DL.org project. It adopts a multi-level approach, along the classification of the European Interoperability Framework for eGovernment services (IDABC, 2004):

- *organizational interoperability*: refers to the cooperation between and within digital library organizations, business goals and process modelling;
- *semantic interoperability*: refers to understanding the meaning of information in digital libraries;
- *technical interoperability*: refers to interconnection, presentation and exchange of digital objects within digital library, accessibility and security issues.

4.2 The rights

During the process of information exchanging thorough the Web, there arises inevitably necessity of keeping the rights of authors and users of digital information. By his nature, the objects, presented in digital space can be:

- *digitally born art-objects*. These new kind of masterpieces live in digital media, which is their primary environment;
- *digital images of analogue art-objects*. Here a digitized work of art is not the work itself but an image (instance) of this work;
- *objects, which are connected with other art-objects*. For instance, an essay over some painting period of the artists, or sketch representing main characteristics of the artwork.

The standard royalties are expanded with the new ones, concerning life-cycle of digital objects in Web space. One attempt for establishing legal framework for open multimedia supply and consumption to be used by all participants in the chain is made in MPEG-21 (MPEG-21, 2002). It defines a "Rights Expression Language" standard as a means of sharing digital rights/permissions/restrictions for digital content from content creator to content consumer. As an XML-based standard, MPEG-21 is designed to communicate machine-readable license information and to do so in a "ubiquitous, unambiguous and secure" manner. This open framework provides content creators, producers, distributors, representatives and service opportunities of the existing free market. This also benefits consumers by providing access to a wide variety of content in an interoperable way. MPEG-21 is based on two basic concepts:

- A basic *unit* of distribution and transaction – a digital item – which is "object" in the multimedia framework (e.g., video art, music album);
- The concept of *user* interacting with him, which is "subject" in this framework.

The main purpose of MPEG-21 is the defining technologies needed to support consumer access to digital items and their free exchange, use, trading and manipulation in an efficient and transparent manner.

4.3 Semantic Web

During the years, the ability of processing the information as well as expanding the ways of data exchanging is increasing in parallel. The development of computing and communication capacities allows to place the user in the central point of the process of information exchange and to enable him to use all power of the intellectualized tools for satisfying his wishes. Amit Agarwal (Agarwal, 2009) provides a simple and clear comparison between Web 1.0, Web 2.0 and Web 3.0 (Table 1).

Web 1.0	Web 2.0	Web 3.0
"the mostly read only web"	"the wildly read-write web"	"the portable personal web"
Focused on companies	Focused on communities	Focused on the individual
Home pages	Blogs	Lifestream
Owning content	Sharing content	Consolidating dynamic content
Britannica Online	Wikipedia	The semantic web
Directories ("taxonomy")	Tagging ("folksonomy")	User behavior ("me-onomy")
Netscape	Google, Flickr, YouTube	iGoogle, NetVibes

Table 1. "Comparison table" between Web 1.0, Web 2.0, Web 3.0 (excerpt from (Agarwal, 2009))

Starting from read-only content and static HTML websites in Web 1.0, where people are only passive receivers of the information, Web 2.0 became as participation platform, which allows users not only to consume but also to contribute information through blogs or sites like Flickr (http://www.flickr.com/), YouTube (http://www.youtube.com/), etc. These sites may have an "Architecture of participation" that encourages users to add value to the application as they use it.
According to David Best (Best, 2006), the characteristics of Web 2.0 are: rich user experience, user participation, dynamic content, metadata, web standards and scalability. Further characteristics such as openness, freedom and collective intelligence by way of user participation, can also be considered as essential attributes of Web 2.0.
The pros and cons of using such paradigm as well as other one are many; for a good range of initiatives of social media outreach in the cultural heritage institutions see (WIDWISAWN, 2008). Let´s mention alternatives, discussed from Eric Raymond in (Raymond, 1999) concerned two fundamentally different development styles, the "cathedral" model of most of the commercial world versus the "bazaar" model of the Linux open-source world, where the advantages of such social self-build systems are shown. Here, the situation is similar. For instance, while the Encyclopaedia Britannica Online (http://www.britannica.com/) relies upon experts to create articles and releases them periodically in publications, Wikipedia relies on anonymous users to constantly and quickly contribute information. And, as in many examples, the happy medium is the right position. Many art repositories and portals are used for educational purposes; consequently control over the main presented text is very important. On the other hand, they are natural places for users to share their own opinion and to have a space for communication. The interest of users measured in number of hits and traces of their activity grows when they are able to add their own content or to comment on existing commentaries.
In the area of art images social networking sites can help extent the number of users consulting an image; for example the Library of Congress explained at the American Library Association annual conference in 2010 that the number of visitors consulting images which can be both accessed on the Library of Congress website and on flickr.com attracted higher number of visitors on flickr. The user generated comments on flickr also helped to improve the metadata records the Library maintained.
Not much time passed before the idea of "Web 3.0" appeared. Amit Agarwal states that Web 3.0 is about semantic web (or the meaning of data), personalization (e.g. iGoogle), intelligent search and behavioural advertising among other things. While Web 2.0 uses the Internet to make connections between people, Web 3.0 will use the Internet to make connections with information. The intelligent browsers will analyze the complex requests of the user given in natural language, search the Internet for all possible answers, and then organize the results for him. The adaptation to user specifics and aptitudes will be based on capturing the historical information thorough searching the Web. Many of the experts believe that the Web 3.0 browser will act like a personal assistant. The computer and the environment will become artificial subjects, which will pretend to communicate in real manner as real humans. Of course, the problems of applying rights policies in such a new atmosphere are crucial.
However, addressing the rights is an additional issue which needs to be solved. A core problem in this domain is which combination of retrieval methods and techniques can lead to high quality image discovery.

5. CONCLUSIONS

We presented in this paper a succinct overview of the development of repositories of digital art images and then highlighted the specialized search methods in this domain. Compared to other cultural heritage materials, to improve the accessibility of digitized art images, a transition in the methods is requested from approaches involving only textual metadata towards "hybrid" approaches of retrieval using content based image retrieval jointly with the metadata. Linked data is also an essential trend to integrate better; however it could rather help to contextualise art images within additional scattered information available on the web. Methods for analysis of the image content are the only current possibility to achieve accessibility which would also address characteristics of the images themselves besides those which had been given as metadata.
As in other cultural heritage domains, digital art images also require methods to resolve art issues and to experiment with and implement approaches for involving the users without compromising the trustworthiness of the resources.
We believe that areas which will develop with a priority in the very near future are:

- Further refining of specialized image retrieval techniques seeking to both improve the quality of the analysis and to overcome the semantic gap;
- Defining best practices in involving the users (individual users as well as communities of users);

- Sustaining trustworthiness of the resources when social media tools are used to add user generated content;
- Improving not only the information delivery but also the user experiences and expanding the delivery of information with immersing technologies.

The ultimate goal is to facilitate the access to art objects in digital form and to convert it to fun and a great experience.

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LOW COST WEB-BASED APPLICATIONS FOR CULTURAL HERITAGE

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KEY WORDS: Low cost documentation, e-Cultural Heritage, Web-based cultural heritage, GIS and Cultural heritage

ABSTRACT:
Computational methods are increasingly gaining recognition as a means of great significance for the management of Cultural Heritage worldwide. The storage and dissemination of archaeological data over the Internet may be a valuable source of easily accessible e-information around the world. This paper presents two free softwares that have been used for low cost e-documentation of Cultural Heritage, namely Google Earth API and Google Sketch-up. These softwares are dynamically growing tools that can be used for building a web-based system for the recording and documentation of archaeological monuments.
The church of Ayia Napa in Limassol and the Kolossi Castle at Episkopi, both in Cyprus, are used as cases studies. These monuments are displayed in 3D format and embedded into a web page. The end-users of the web page can then find the 3D representation of these monuments in a 3D digital globe, like they are in real world. Such methods can be a valuable tool for institutions and museums that are responsible for the documentation, preservation and promotion of Cultural Heritage. Through this method, a digital archive can be created, one that will be accessible to the public, the proper carrier of the international archaeological Heritage.

1. INTRODUCTION

The integration of information technologies and cultural heritage can impact in many ways the information regarding Cultural Heritage. The cultural heritage community has recently been attracted by the chance offered by information technology, and, in particular, by the possibility of making cultural information available to a wide range of people (Bonfigli et al., 2004). Furthermore recent developments in the scientific methods of documentation also influenced the conservation approaches of historic areas, sites and monuments.
There has been a sudden increase of mapping applications on the web such as Google Maps and Bing Maps. Geographical Information Systems (GIS) have become very popular around the world as they can spread information with a straightforward and simple process. The present paper describes a method for building a 3D web-based system for recording and visualising Cultural Heritage monuments. The system shares multidimensional information like dynamic maps and historical 3D data. Much commercial softwares are available for this purpose. In this case the authors have chosen to use a type of software which is free and provides easy access to the data. The only necessary prerequisites are a web browser, the installation of Google Earth plug-in and an Internet connection.
Moreover advances in the field of GIS offered the appropriate tools for the central and local authorities responsible for cultural heritage to build corporate information systems having this type of information technology as one of the most important infrastructure component, as highlighted by Petrescu (2007).
Previous attempts of using web-based GIS for managing byzantine churches in Cyprus are well demonstrated by Agapiou et al. (2008; 2010). Indeed, this study intended to contribute significantly in this field of area by using more advanced data management platform, the 'Apollo Leica' that is owned by the Cyprus University of Technology.
(Guarnieri et al. 2010) reports that new opportunities and challenges for the development of web-based Virtual Reality (VR) applications in the field of Cultural Heritage have been the direct effect of advances in the field of surveying and Internet-related technology. Web-based virtual tour applications constructed by 360º panoramic images are already being used extensively all over the world (Bastanlar et al., 2004).
The aim of the present paper is to demonstrate how a low cost web-based application can provide a simple mean through which Cultural Heritage can be documented and also accessed by the public. This method can be proven to be a most useful tool for institutions such as the Department of Antiquities of Cyprus.

2. GEOGRAPHICAL INFORMATION SYSTEMS

The advantage of GIS is based on their ability of updating their geographical information index in a continuous and interactive mode, processing and storing large volume of diverse origin data and creating thematic maps based on specific inquiries. The above can be used in archaeological research for modeling the diachronic settlement patterns of a region, locating and outlining the limits of high probability archaeological candidate sites, studying the communication or defensive networks, specifying cost surface regions used for the exploitation of natural resources, etc. The development and construction of digital thematic maps that present various cultural and environmental information, could be extremely useful in solving problems resulted by the environmental and development plans, suggesting specific solutions for the protection, preservation and management of ancient monuments.

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Previous studies such as Hadjimitsis et al. (2006) that used GIS for managing cultural heritage sites in Cyprus explored the effectiveness of this tool as combined with remote sensing (see Figures 1 and 2). The need for continuous insertion of all related information will create a complete system of monitoring cultural sites / monuments around the whole island of Cyprus as reported by Hadjimitsis et al. (2006).

Figure 1: GIS data in conjunction with Quickbird satellite image data acquired on 23/12/2003: 'House of Theseus at Kato Paphos Paphos'

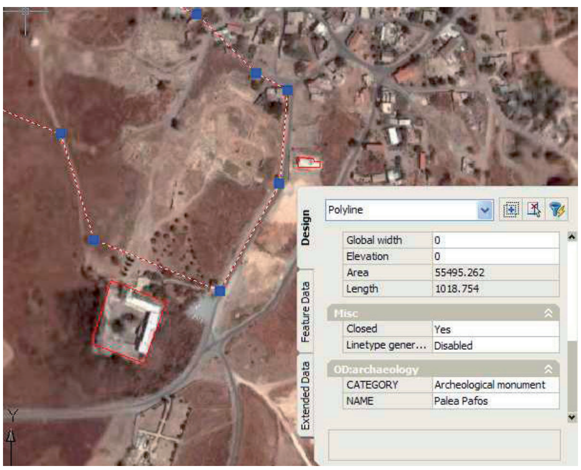


Figure 2: Sample snap-shot showing the use of GIS in conjunction with satellite image (Quickbird) acquired on 23/12/2003 for the Aphrodite Temple at Kouklia in Paphos

Using the ERDAS APOLLO software one can integrate the geospatial data into an existing web site or software application. ERDAS APOLLO uses standards that are publicly available on the internet and recognized worldwide Moreover the user can configured in any web site or application these standards and access the data (ERDAS Guide, 2010).

ERDAS APOLLO services framework architecture has three programming interface layers in order to manipulate the data. These are: a) the Open GIS Interfaces, b) ERDAS Engine and c) the c) Data Connectors. There is also the configuration files that are accessed by the Data Connectors layer (Figure 3).

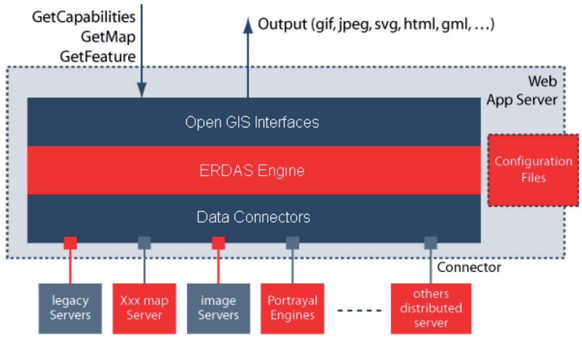


Figure 3: ERDAS APOLLO framework architecture

This software supports both raster and vector data, coordinates transformations, while security can be performed in order to access or not the data from the web (Figure 4).

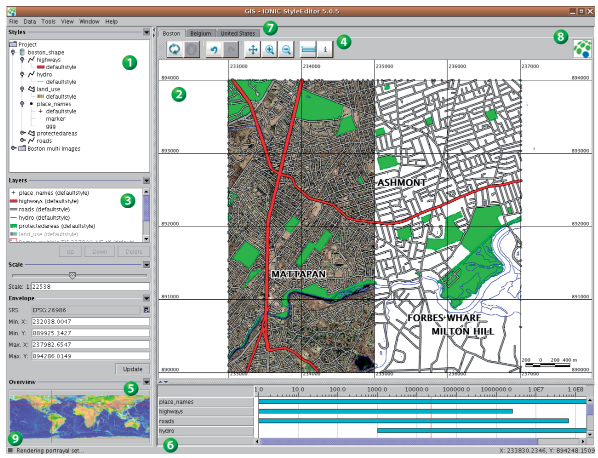


Figure 4: ERDAS APOLLO framework architecture (ERDAS Guide, 2010)

3. DATA AND SOFTWARE

3.1 Digital Cartography

Computer technology is rapidly advancing and new technologies are continually presented. The revolutions of the web, along with the advancements in digital cartography, have given the opportunity to share geographic information around the world with dynamic maps. GIS can combine both spatial and non-spatial information into one uniform interface. In this case the end-user may in the same time see the location of the monument on a 2D or 3D map while in the same time he/she can read the historical background of the monument a.o. Furthermore in a GIS environment queries may be performed while at the same time spatial analysis can be made in GIS.

However GIS softwares capabilities vary according to the end-users needs. ArcGIS, AutoCAD Map softwares are a few examples of sophisticated softwares while on the other there are freely available GIS softwares, such as the one provided by Google.

Google is one of the largest companies of the web with many programs available at no cost. One of Google's newest tool is Google Earth Application Programming Interface (Google Earth API). This is a plug-in which can help developers to

embed Google Earth applications into web pages with JavaScript code.
The present paper takes advantage of the available new technologies of digital cartography in order to demonstrate how monuments in 3D format can be presented set in their landscape. As it is shown in Figure 5 Google Earth has already been used successfully for the documentation of cultural heritage monuments.

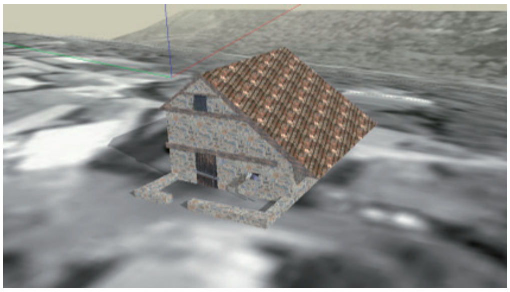


Figure 5: Byzantine Church of Cyprus in Google Earth (Agapiou et al. 2010)

3.2 Internet

Nowadays Internet is established as the par excellence tool for spreading information. People and especially the young generation can easily use it. Cultural Heritage should be easily available to the public and, therefore, the best available method to achieve this is through the wide use of Internet.
The spatial information can be shared over the Internet in many ways (text, photos, videos a.o.). Through the distribution of geographic information, users have easy access to large databases. The integration of Internet technology and GIS provides several advantages to simplify the management andaccess to the information. Indeed, the use of internet technologies to provide access to spatial information and GIS on the internet provides the comprehensive documentation and management of cultural heritage as shown by several other researchers such as Pescarin et al. (2005).

3.3 Digital management of Cultural Heritage

Digital Cartography and the Internet are already being used for implementing virtual 3D or 2D tours by a number of institutions, such as Museums, Cultural Foundations and Universities.
The Greek *Foundation of the Hellenic World* is one of them. The website of the *Foundation of the Hellenic World* (http://www.fhw.gr/fhw/) provides a lot of information on the cultural heritage of ancient Greece and, in some cases, 3D virtual tours. Another example is the website of the *Institute of Technologies Applied to Cultural Heritage* with the "Appia Antica Project" (http://www.appia.itabc.cnr.it/) and the *Inuit 3D Museum* of the *Canadian Museum of Civilization* (http://www.civilization.ca/cmc/exhibitions/aborig/inuit3d/vmcinuit_e.shtml).

4. CASES STUDIES

The monuments that we use in our study are the church of Ayia Napa in Limassol and the Medieval castle of Kolossi at Episkopi. The tools which we use are Google Earth API plug-in and the free edition of Google Sketchup. The Google plug-in is used in order to integrate a 3D globe into a web site and for easy navigation to the area of interest. Google Sketchup is used for building the 3D models of the two monuments. Both tools are free but closed source.

4.1. The Kolossi Castle, Limassol

The Kolossi Castle (Figure 6) is a stronghold located a few kilometres outside the city of Limassol. It held great strategic importance and was dedicated for the production of sugar, one of Cyprus' main exports in the Middle Ages. The original castle was possibly built in 1210 by the Frankish military when the land of Kolossi was given to the Knights of the Order of Saint John of Jerusalem by King Hugh III. The castle in its present form was built in 1454 by the Hospitallers. Richard I of England and the Templars were some of the castle's residents.

Figure 6: Kolossi Castle in Limassol

4.2. The Church of Ayia Napa

The church of Ayia Napa (Figure 7) is located in the old town of Limassol. It was built during the Ottoman period (early 18th century) on the ruins of an earlier Byzantine church. In 1891 it was in turn replaced by a larger structure that was completed in 1906.

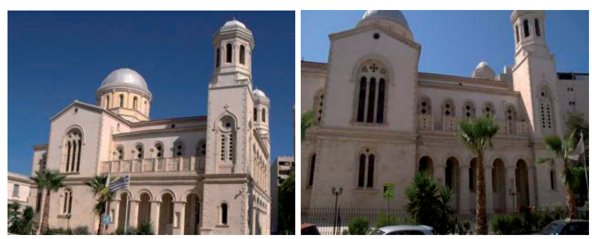


Figure 7: The church of Ayia Napa in the centre of Limassol

5. METHODOLOGY

The overall methodology of this study is described below:

- Take photographs of the monument under investigation. To capture the images of the buildings we have used a digital camera with 10.1 Megapixel. In-situ topometrical measurements were carried out.
- Reconstruct the 3D models (Figures 8-9) of the buildings in Sketchup. Then the photos were joined together.
- Build up the web site and embed the Google Earth API plug-in and the 3D models.
- Management of the data by the ERDAS APOLLO software (in progress).

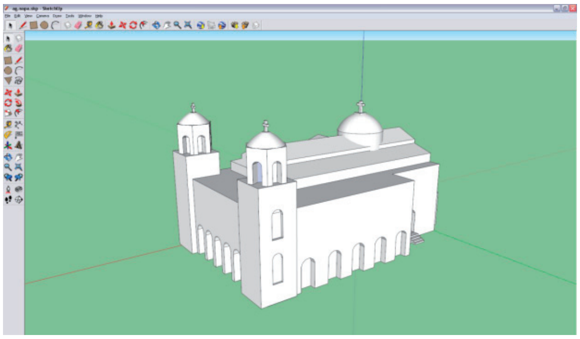


Figure 8: 3D model of the Church of Ayia Napa in Google Sketch up software

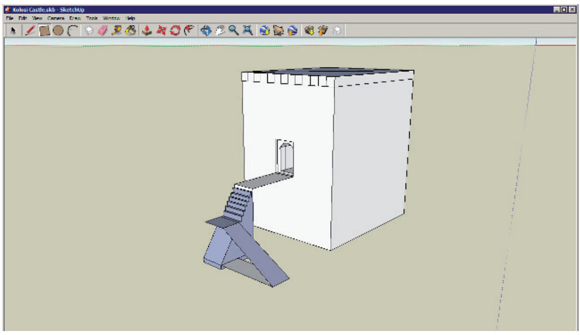
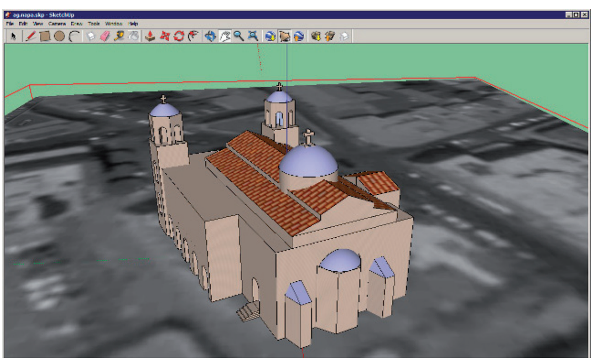


Figure 9: 3D model of the Kolossi castle in Google Sketchup software

The 3D models were at first stage designed using the in-situ topometrical measurements. Texture was used for the models based from the libraries of the software, for a more realistic result (Figure 10). These models should be minimised in capacity (e.g. less than 10 Mb) in order to achieve better and real time results in 3D viewers. This, however, has an impact on the accuracy and the detailed rendering of the final 3D model.



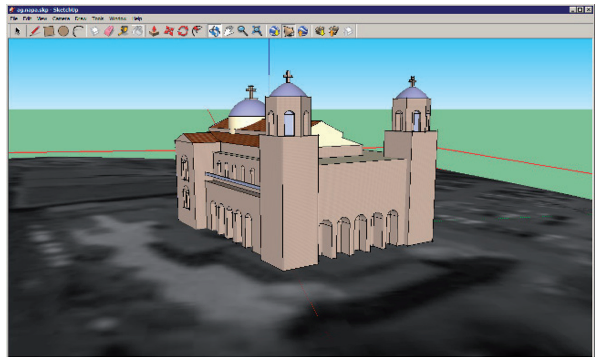


Figure 10: Textured 3D models in SketchUp (Church of Ayia Napa)

These models can be more realistically rendered if shadows are displayed, as it is shown in Figure 11.

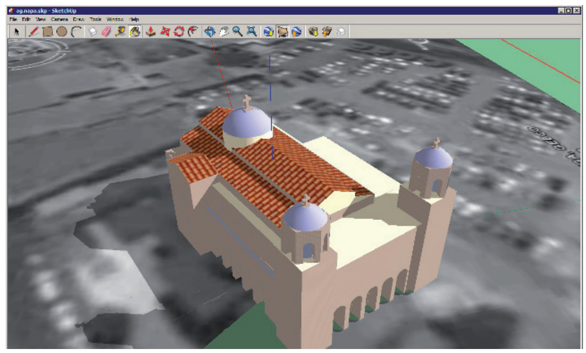


Figure 11: Textured 3D models in SketchUp using shadows (Church of Ayia Napa)

6. RESULTS

Online information about historical Heritage of areas and buildings has been published temporally on an internal view and at a later stage will be in an open public eye. All information can be integrated in a 3D globe which is navigable. This information can be stored in a database for better and faster results. The view will be very close to reality with 3D globe and reconstructed buildings. This study in fact regards the creation of a 3D spatial archive of the monuments of Cyprus or in specific areas exhibits.

As it shown in Figure 12 the 3D models can be display in 3D global viewers such as Google Earth.

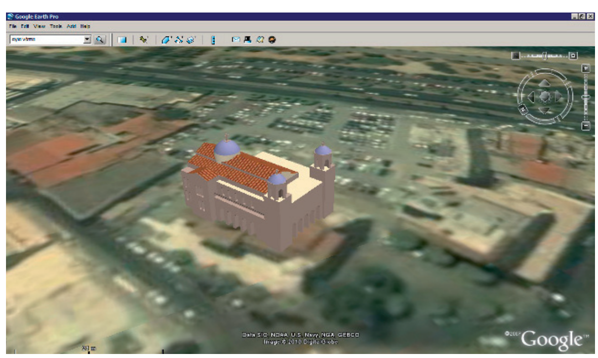


Figure 12: 3D model of Ayia Napa, in Google Earth

Historical information regarding the monuments can be displayed in 3D globes, so that the end-users can read in brief the historical background of these monuments (Figures 13-14).

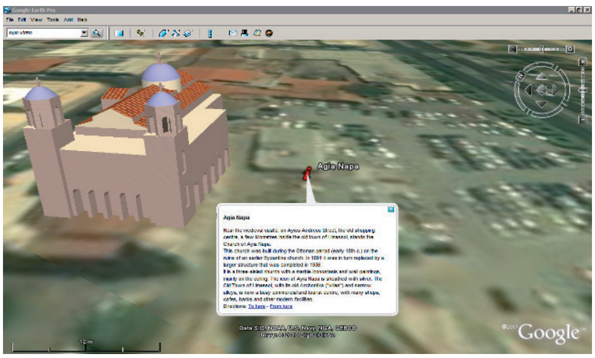


Figure 13: Historical information as displayed in Google Earth

Figure 14: Information displayed in Google Earth

Using the free software Hugin v. 4 the authors have built360^{o} panoramic views of the church of Ayia Napa in Limassol. The specific software is an easy-to-use unified point-and-click interface to a whole range of other command-line tools. The recently taken photographs were inserted in the Hugin software and using the points for connecting the photos, the 360^{o} result was exported. In Figure 15 screenshots of the procedure of tie points is demonstrated while in Figure 16 a part of the final 360^{o} is presented. However, it should be emphasized that this method is only used for demonstrating in a dynamic way the monument without any geometrical accuracy.

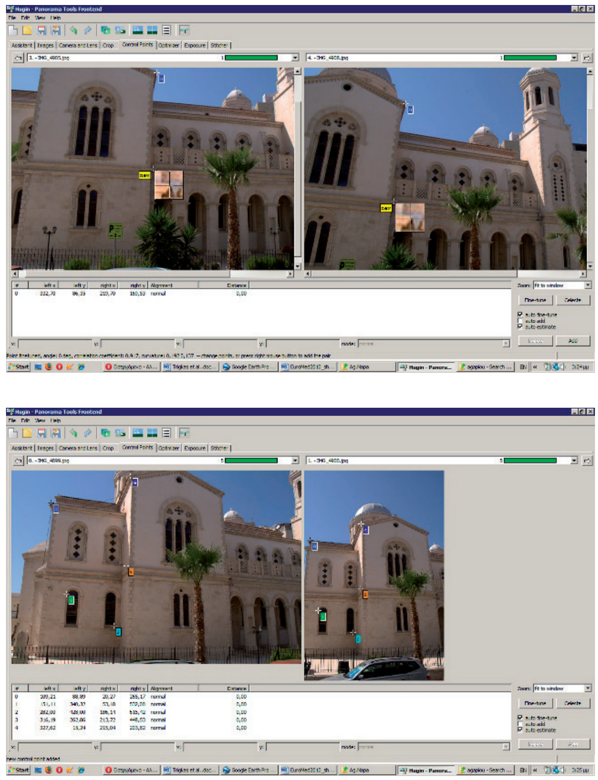


Figure 15: Tie points used in the Hugin software

Figure 16: Part of the 360^{o} panoramic view

The final result was uploaded to the 360^{o} Cities Project of Google Earth. 360^{o} Cities Project is a project that the end-users can upload and view the results of high resolution 360^{o} panoramic views. Such embedded technologies can be used not only for monuments but and also for small objects such as icons, frescoes, paintings a.o (Figure 17).

Figure 17: Ayia Napa in the 360° Cities Project of Google

7. CONCLUSIONS

Nowadays internet has penetrated in our life. Cultural Heritage needs technologies of Internet for storing or spreading information which scientists create or explore. Low cost or freeware software is a very good solution for scientific research. In this case we have built a site from scratch with free tools, with a promising result and easy way to spread and store data. The realistic of the 3D globe gives the opportunity to scientists to present geographical data in a virtual world which is a solution much better and certainly cheaper than forwarding information by printing and buying. Low cost or free software can be a useful tool for scientific research. In this paper we have used Google Earth plug-in which can be downloaded for free. The only prerequisite is access to the Internet. There are a lot of solutions like Google (e.g. ArcExplorer**,** Microsoft Virtual Earth**,** NASA World Wind**,** TerraExplorer and more) which need to give more attention to each. Google Earth plug-in and Sketchup can be a functional and effective tool, as explained before, but there are restrictions on their use because of the fact that they are closed source software. An open source implementation can be more useful, as it can be more easily operated and controlled. There is a large number of open source programs for GIS, WebGIS and 3D applications. An open source implementation can be more useful and the reason is that it is more easily manipulated and it returns control to the scientist. There are a lot of open source programs relating to GIS, WebGIS and 3D WebGIS.
The convergence of the Internet technologies can help scientists promote their ideas and the results they produce. This is the primary goal of every scientific work. In this case we have seen how a low cost or freeware tool for distributing and spreading Cultural Heritage information through the Internet can easily work.

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Presenting the Past

EuroMed2010
3rd International Conference dedicated on Digital Heritage
M. Ioannides, D. Fellner, A. Georgopoulos, D. Hadjimitsis

THE INTERACTION DESIGN SPACE OF A DIGITAL INTERFACE FOR A CULTURAL HERITAGE EXHIBITION

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KEY WORDS: Digital Exhibition, Digital Heritage, Digital Tool, Design Space, Interaction Design, Interface Design, Museum Interpretation

ABSTRACT:

This paper explains the process of the interaction design space for a digital interface within the heritage domain. This digital interface will display online the main pieces of the Xalapa Museum of Anthropology collection. The museum collection draws from the cultural heritage of the Pre-Hispanic cultures that developed in eastern Mexico: *Olmeca, Huaxteca and Central Veracruz*. The paper also describes the phases that shape the interaction design space; the theories that frame the conceptualisation of the digital interface; the rationale for the visualisation concept; and the initial reflection on the design of the interface, tools and social media perspective.

1. INTRODUCTION

1.1 The project context

This project aims to explore design solutions for a digital interface of an archaeological museum collection. The collection draws from the cultural heritage of The Xalapa Museum of Anthropology (*Museo de Antropología de Xalapa*), also known as the MAX, which is sited in Xalapa, Veracruz, in eastern Mexico. The Xalapa Museum of Anthropology additionally hosts a research centre affiliated to *Universidad Veracruzana,* whose mission is to guard, preserve, restore and display the Pre-Hispanic cultures developed in the state of Veracruz as well as to foster research, publication and dissemination of the cultural heritage produced by those cultures (Winfield, 1992).
According to the website of the MAX, its total collection is formed by about 29,000 Pre-Hispanic pieces, from which nearly 2,500 are exhibited in its halls. This collection consists of important cultural-heritage artefacts of the main cultures that established themselves in the current state of Veracruz, before the Spaniards' arrival in Mexico: the *Huaxteca* culture in the north, the culture of *Central Veracruz* in the centre of the state and the *Olmeca* in the south. The collection has a varied assortment of cultural heritage artefacts: typical of the *Huaxteca* culture are feminine figures, old and hunchbacked men, ornaments made of seashells and bones, copper instruments, and animal-shaped vessels; the *Central Veracruz* culture is famous for its articulated figures, smiling faces and figures, obsidian and flint arrowheads, axes, whistles, and fresco paintings; the characteristic artefacts of the *Olmeca* culture are altars, stone colossal heads, and jade masks.
Several sources inform about the collection and the Pre-Hispanic cultures of The Xalapa Museum of Anthropology. On the one hand, there are printed sources, mainly made up of research carried out at the research centre and published by *Universidad Veracruzana*. There are also labels and information graphics, such as maps and timelines, displayed in Spanish, as information points in the exhibition galleries. Additionally, the museum also has an archive of records and photographs of the whole of its collection. On the other hand, as digital sources, there is already one set of high-quality photographs developed especially for this project, and as of this writing, the museum is going through a parallel phase of producing a complete digital archive of its collection as well as a digital database (Ladrón de Guevara, May 2010, personal communication).

1.2 The project scope

This research project investigates ways to design a digital interface for the online exhibition of the main pieces of the MAX collection. The way this digital interface is conceptualised takes into account the fact that the 'language' of digital technology (Manovich, 2007; Lister et al, 2003) enables the creation of a myriad of innovated representations and designs for digital exhibitions. It is also influenced by the viewpoint that the use of digital technology and social strategies has great potential for the development of deeper and richer communication between the museum and its target communities.
The transformation within the cultural heritage sector towards the incorporation of digital technology has been analysed by authors such as Jones-Garmil, 1997; Kenderline & Cameron, 2007; Din & Hecht, 2007; Parry, 2007, 2010; Marty & Burton, 2008; Kalay et al., 2008; and Tallon & Walker, 2008. The former references have been revised for a better understanding of the implications of the use of such technology in the cultural heritage domain. Moreover, it has also contributed to a broader view of the trends and best practices taking place in the interaction of users and the digital projects analysed.
For quite some time now, museums and cultural institutions have been evolving their model of being '[…] repositories of content [towards being] repositories of knowledge' (Marty, 2008, 4). This idea of 'repositories of knowledge' is in line with the use of digital technology, when creating digital exhibitions that amplify the approach to that cultural 'knowledge', which could otherwise be difficult to achieve. Digital interfaces for interpretation do not only enhance the comprehension of the

cultural heritage by the general public, but they can also be used to build social channels that help cultural institutions to discover what the different target communities of visitors require to learn about that cultural heritage.

2. THE DESIGN SPACE

2.1 Conceptualising the digital interface

Currently, the project is in the process of designing the interaction design space; in a broader sense, this means visualising the understandings of what the digital interface will mean to the users (Sharp et al., 2007), by conceptualising 'the designer model', and thus framing the 'conceptual model' of the interface (Norman, 1988, 2004; Johnson & Henderson, 2002).

The first steps into this interaction design space process were commented in Acuña (2010). There, I discussed in more detail the importance of some disciplines that support the design of digital applications, especially, the ones that support digital interfaces, whose goals are to represent and communicate the knowledge embedded in the artefacts of a collection, such as the MAX collection. Those disciplines include: interface design, interaction design, information design, information architecture and navigation. Together they build the first layer for the process of this design, by setting a combination of topics that are studied within those disciplines. Figure 1 (revised from Acuña, 2008) highlights the connections within the topics. The edges are the hub disciplines of those relationships: interface design refers to the system or artefact used to interact with a product; interaction design, referring to the experiences between people and artefacts; and information design, which is the clearly graphical and meaningful representation of information (Acuña, 2010).

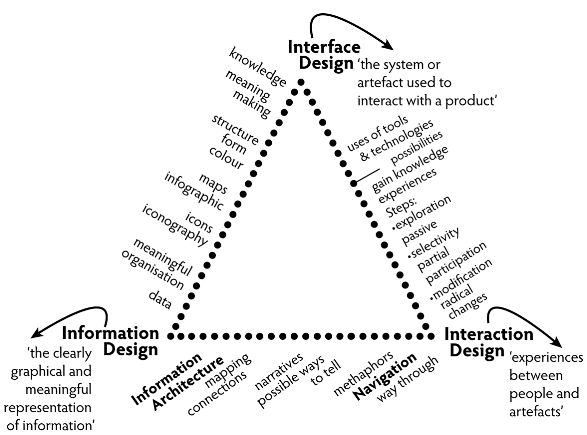

Figure 1: Disciplines framing the interaction design space.

Acuña (2010) also presented a benchmarking analysis of online projects – from museums to cultural institutions – that were developed with the aim to increase the visibility of cultural heritage.

In connection to the research, this paper furthers these ideas for the development of the process of the interaction design space, and aims towards the development of a prototype for the digital interface. It draws on the previous study and also feeds on the vision to create a digital interface to support research, to provide information and to enable access to learning resources about the MAX collection. It thus supports the interests of the three identified target audiences of the museum:

1. Professional interest: researchers, scholars and higher education students that are searching for the essential and in-depth information;
2. Visitors' interest: youngsters and adults looking to become informed;
3. Students' interests: students at primary and secondary level studying the essential history of the Pre-Hispanic cultures.

To cater for the various interests and expectations of these three target audiences, the design of the digital interface will explore multiple pathways for the interpretation of the collection and its context, by building on the diverse interpretations within the contexts of the cultures: such as layers of timelines, cosmology, iconography, language and the like.

2.2 The digital layers of context

The context framework is a very important strand in the cultural heritage domain. Institutions such as museums, archives, galleries, art and cultural centres have always been searching for ways to draw attention to the information and knowledge embedded within their assets, by exploring different interpretation and curatorial activities. It is beyond the scope of this paper to give an analysis of the history and practices of interpretation within the cultural heritage domain, but rather, the discussion will focus on the shift towards the creation of digital interfaces for interpretation, and how the interpretation layers of the collection will be designed within this project.

Over the last years, there has been a trend to design digital interfaces that can increase the interpretation of exhibitions. Moreover, the research for the development of such types of digital interfaces is also focusing on the analysis of the audiences' specific interests so that the planning of the design of the digital interfaces can be created in accordance to those needs. The mixture of digital tools used and the methodological approaches are diverse.

The next section presents the diverse threads that were identified in some digital projects, and that have incorporated thoughts on the concept of the interaction design space.

The concept of 'personalisation' is an umbrella term that encompasses: adaptable systems, adaptability systems and segmentation (Filippini-Fantoni, 2003). The first system is understood as the customisation of the experience; that is, the user decides the configuration of the interface. In the second one, the system adapts to the user needs (with the help of intelligent agents), while the third one occurs when a group of user preferences are taken into account by the system, so it performs accordingly to these preferences (2003).

These approaches have led to the design of websites that integrate any of the following schemes:

- 'my collection': The Library of Congress (http://myloc.gov/pages/default.aspx); The Museum of Modern Art, MOMA (http://myloc.gov/pages/default.aspx), where it is possible to save and annotate artworks from the collection; The National Maritime Museum, where visitors can bookmark, group and annotate objects.

- 'my museum': The Metropolitan Museum of Art (http://www.metmuseum.org/mymetmuseum/) uses the myMet museum and myMet Calendar; The Australian Museum, dedicated to the nature and culture of Australia (http://australianmuseum.net.au/Sign-up), offers the possibility to add comments and tags as well as collect, gather and share favourite items, movies and audio files.

- 'my gallery': TATE KIDS, belonging to TATE Gallery (http://kids.tate.org.uk/mygallery/gallery_home). This website was specially designed for kids. Here small children can build their own gallery from a selected database of 500 works.

Another interesting approach focuses on the target groups that might be interested in the collection. An example is the MOMA website that has recently been redesigned (2010). In this website, visitors have several profile options to choose from (first time visitor, returning visitor, doing research, student, exploring with family, educator). There is also a broad set of possibilities to search and display their collection.

Alternative threads to incorporate views on contextualising information about collections and artefacts are those using the concept of mapping relationships. One example is the project 'The Museum's Mind: a Cybermap for Cultural Exhibitions' (Forte & Pietroni, 2006). In this project, the researchers are developing a concept of a 'cybermap' to create relationships between visitors and the museums' artefacts. In their conceptualisation, the map works as 'a cognitive space' where contents can be 'associated' with shapes and colours in a 3D environment. In Pietroni & Forte (2007), the researchers proposed a virtual scenario to support exchange and collaboration within scientific communities, where the concept of 'cybermap' works as a key 'interpretative process'. As these authors stated: 'Priority of museum information consists in the contextualization of data and cultural relations' (2006, 70).

The concept of mapping relationships is highly connected with another important thread that has given insights into the concept design space for this project; namely, the model of visualisations. The term model is used here as 'the way to design and represent information and its corresponding mappings'. It is not meant to be strictly the idea of giving only visual form to complex structures of abstract data. An example of this approach can be seen in the interactive installation 'mæve' (MACE-Everyville) developed by the University of Applied Sciences in Potsdam, Germany (http://portal.mace-project.eu/maeve/installation.php). This digital exhibition uses touch screen technology. The design plays with the idea of connecting networks of information by placing tangible cards on the interactive surface. By so doing, the system visualises the mapping of the information on the screen. The connections and the mapping grow in accordance to the selection of the users when interacting with the digital interface.

3. THE DIGITAL PROJECT

3.1 The interface approach

Considering the above, the design conception of the digital interface for exploring the main pieces of the collection is the result of bonding together ideas about the visualisation of information, context mapping and trails of navigation. The project innovation is the exploration of cultural information presentation through the design of an interface based on connections of visualisations.

The approach is to design a digital interface that privileges exploration and browsing of visual connections with an open-ended focus; namely, an interface that allows a visitor to place an 'object/concept' at the centre of his/her interpretative layer, and thus create a hub of connections. Because the interaction towards the 'object/concept' is open and depends on the visitor's exploration and interests, this idea also allows serendipity and further creation of interpretative layers as the exploration continues.

The cultural content of the project can be accessed through a variety of requirements that have been set for the main collection, which are: culture, iconography, cosmovision, formal features, materials, techniques, artefact type, place of origin, date, and geographical location among others. Due to the fact that the digital interface will be used only for the exploration of the main pieces of the collection, it is possible to use diverse layers of that cultural content in an atomized way. This latter fact supports the concept design of using support visualisations for interfacing the main collection. Moreover, since the previous categories also have subcategories, those can also be used as hubs for interfacing the main collection.

Some of the challenges in relation to the design concept of this digital interface are: How to set the parameters for delivering the cultural information? How to avoid overload of different connections that could create misinterpretation of the delivered information? How to design the interface for trails of navigation that were followed, so that they can be used again for interfacing the digital exhibition and at the same time bring extra cultural content? How to atomize the visual connections?

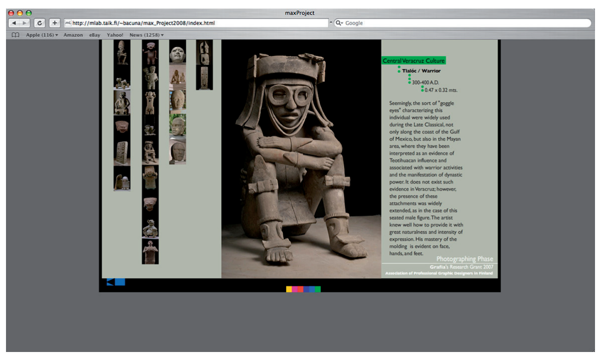

Figure 2: Prototyping example.

Although parallel approaches have been applied to information visualisation projects fed by online databases, no much in-depth research have yet been done on the design of interfaces that are created as such for cultural heritage collections. Many cultural heritage repositories and digital libraries have focused the design of their interfaces on displaying and labelling the artefacts of the collections, rather than contributed to the design of visual interpretation interfaces.

3.2 The interface and tools

As of this writing, the project is still in the process of designing the interaction design space, so that only an initial overview of the digital interface has been developed so far. This initial overview is drawn from the MAX collection's culture-specific contexts that can be used for creating digital mappings, for example, the concept of *Dualidad* (duality).

The concept of *Dualidad* highlights the cosmovision of the Pre-Hispanic cultures portrayed in the MAX collection. This concept of duality is a 'fundamental idea' in the Pre-Hispanic world: 'The balance of the universe, in all possible ways, is based on this concept' (Ladrón de Guevara, 2008, 9, translation by the author). In the MAX collection, many of the artefacts of the *Huaxteca, Olmeca* and *Central Veracruz* cultures embody this cosmovision of *Dualidad*: feminine-masculine, life-death, twins, natural-spiritual, or duplicity, to mention but a few. ‘The peculiarity of this way to see the world integrates in a balanced way aspects that are apparently opposed, but complementary’ (Ladrón de Guevara, 2008, 9, translation by the author). In conclusion, duality is a complex context that connects not only the three cultures, but also other concepts and the artefacts from one collection to the other.

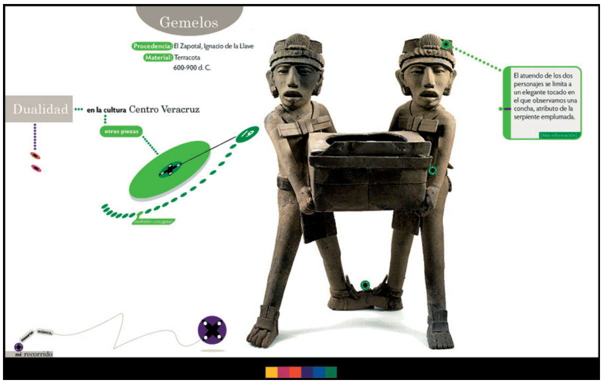

Figure 3: Prototyping example
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Following is an initial overview of the design of the digital interface. The digital interface presents a set of tools that supports the visitor at exploring several ‘object/concept’ visualisations. When browsing the visualisations, a visitor has the choice to select any category as a main hub. For example, when the visitor selects the hub *Dualidad*, the interface presents some other visualisations of ‘object/concept’ that are connected to this selection, such as the artefacts of smiling faces and smiling figures. Then, the visitor decides to access more information about a specific smiling figure. The result of this interaction is another mapping of ‘object/concept’, for instance, ceremonial contexts, concepts of death, joy, fertility, and the *ollin* (movement). If the visitor continues to explore the site and decides to discover more about the *ollin* concept, this can be selected as the main hub. In consequence, the interface will present a selection of results connected to the iconography category, including movement and myths of creation.
In addition, the digital interface will make use of other tools to support the visualisation of the cultural information: either to set different view-structures, or to display information such as the number of artefacts that are related to the ‘object/concept’ selected, and the number of times that the concept is related to different information. A variety of additional tools will be incorporated into the interface, such as tools for grabbing objects, zooming in and out objects, annotating objects and the like; as well as tools to keep track of the diverse mappings and to help with the navigation. Still more interactive tools will be proposed during the design and prototyping stages.

3.3 The social media perspective: a proposal

An additional phase in the process of the interaction design space for the digital interface is the one linked to the museum and its communities of visitors. Lately, there has been a growing emphasis on community participation, user-generated content and the use of social media tools. All of them are part of the stream of Web 2.0 technology (O’ Reilly, 2005).
Due to this trend and increasing interest in social activities as well as community building online, museums and cultural institutions have also introduced social Web strategies. In particular, these are used for trying to build communication channels with their active visitors and with the potential ones. Although this process is on the increase, there is still not a great body of research on it, nor are there a great many studies about visitors’ practices when using social media within the cultural heritage domain.
The design of the digital interface of the Max main collection gives priority to bridging communication between the Max museum and its different communities, by incorporating a design space for social media tools in the digital interface of its collection. The agenda is to foster the curiosity of the target communities about the Pre-Hispanic cultures that are exhibited in the museum. The digital interface also intends to be used as a channel for social participation between the museum stakeholders and the visitors. It is expected that structuring and building a channel for social participation will contribute to these communities’ further interest in the museum collection and the museum cultural activities.
More research has to be done in order to complete the framework for the design space of the social media tools that will be created for the Max main collection. The above information has presented a general overview of this stage of the study and the follow-up work for this project includes the description of the set of social media tools to be designed for the digital interface.

4. CONCLUSION

The use of digital technology for the support of interpretation and curatorial activities within the domain of cultural institutions is on the rise; this technology has brought open-ended possibilities of interpretation and creation of digital exhibitions. Since interpretation influences the way to display, inform, disseminate, and communicate the context and cultural relations embedded in the exhibited artefacts, these institutions are exploring new forms of delivering such knowledge by using digital interfaces.
The design of digital interfaces for cultural interpretation has to take into account frameworks from a range of disciplines. In addition, it has to be fed by an analysis of the contexts of the material to be exhibited, so that these contexts can be interfaced with the appropriate digital design. Another important strand that has to be researched when designing digital interfaces is Web 2.0 technology. The current trend in the design and use of social media tools offers additional channels of communication between the stakeholders and the visitors of cultural institutions, and thus, these tools can be used as a strategy to build interests towards cultural heritage.
This paper has presented a proposal for the interaction design space of the digital interface that will be used for the interpretation of a museum collection in eastern Mexico. It has analysed the insights into the conceptualisation of the digital interface and has discussed the rationale for proposing this interface based on the exploration and browsing of visual connections, context mapping and trails of navigation. The ultimate goal for this particular interface is to support the visitors’ interpretation by using connections or hubs of visualisations.
Finally, the paper also proposed that the design of the digital interface should explore the incorporation of social media tools as a strategy to reach out to visitors, as well as to increase their interest towards the Pre-Hispanic legacy. The next stage of the project will focus on the total completion of the interaction design space of the digital interface, by defining the design of all the digital tools and the social media perspective.

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TARRACOMAP: DEVELOPMENT OF AN ARCHAEOLOGICAL APPLICATION ON GOOGLE MAPS NAVIGATION SYSTEM

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KEY WORDS: GIS, Web-focused Project, Tarraco, Google Maps

ABSTRACT:

This paper describes the result of a research about diverse areas of the information technology world applied to cartography. Its final result is a complete and custom geographic information web system, designed and implemented to manage archaeological information of the city of Tarragona. The goal of the platform is to show on a web-focused application geographical and alphanumerical data and to provide concrete queries to explorate this. Various tools, between others, have been used: the *PostgreSQL* database management system in conjunction with its geographical extension *PostGIS*, the geographic server *GeoServer*, the *GeoWebCache* tile caching, the maps viewer and maps and satellite imagery from *Google Maps*, locations imagery from *Google Street View*, and other open source libraries. The technology has been chosen from an investigation of the requirements of the project, and has taken great part of its development. Except from the Google Maps tools which are not open source but are free, all design has been implemented with open source and free tools.

1. INTRODUCTION

The work presented here is part of a collaboration agreement between the Institut Català d'Arqueologia Clàssica (ICAC), and the Architectures and Telematic Services research group from the Computer Engineering and Mathematics Department of the Universitat Rovira i Virgili (AST-DEIM).

1.1 Motivation

During the Roman Empire Tarragona was capital of the *Hispania Tarraconensis*, highlighted by great entity monumental sets like the Fórum Provincial, the circus, the Theater, the amphitheater or one of the most important late antique necropolis of Western Europe. Under this circumstances the creation of a computerized environment in which we could manage the archaeological activity of Tarragona has been a long story which started in 80's through the work of TED'A (TED'A 1989) and the contributions made by the SICAUT (Ruiz de Arbulo, Mar 1999). These teams worked only with alphanumeric data as data element, through database managament systems without relational connection between tables (DBIII and DBIV). This approach was brought to its technological limit with the creation about the archaeological interventions conducted in Tarragona (Rifà 2000) in a project done in collaboration by the Museu d'Història de Tarragona and the Institut d'Arqueologia of the Universitat Rovira i Virgili (subsequent ICAC). The change of methodological perspective was motivated because the impossibility to create an environment on database (Filemaker Pro 5.0) in which coexist both textual data and CAD offering a joint visual and spatial perspective of the archaeological context of a growing city like Tarragona. The GIS solution emerges seeing how this problem was solved in other European urban contexts. So in 2002, a first methodological proposal emerges (Fiz 2002) using Arcview 3.1 as GIS environment. In 2004, on the PhD of one of the authors goes beyond the methodological and creates a GIS environment to manage archaeological activity of Tarragona. In 2007 the Planimetría arqueológica de Tarragona (Macias, Fiz, Piñol, Miró, 2007), a project done in collaboration between the ICAC, the Museu d'Història de Tarragona and Generalitat de Catalunya was published, and the first analysis was obtained of this information (Fiz, Macias 2007). This project, however, makes a mistake because it only focuses in the century period VI BC to 712 AD.
Having in mind that Tarragona is a city refounded in 1235 on Roman foundations, and between centuries XVII and XVIII is endowed with a major belt of fortifications, and the model had not been developed and validated completely, this severe slip, raised in 2008 (Macias, Fiz *in press*) to propose two future work lines. On the one hand to develop a GIS extension on free software using gvSIG and allowing archaeological management or any other city, and on the other hand to search ways to spread and publish through Internet the archaeological information of the city. At this point a collaboration between the ICAC and the Departament d'Enginyeria Informàtica i Matemàtiques was defined in order to get both projects running. We present the results of the second project here.

1.2 Overview

TARRACOMAP is created as a computing solution to accomplish the previously described needs. A client-server application has been developed, in order to keep updated on the ground the set of archaeological actions done and all the information that was generated around it. The application will be available on the Internet and will allow to display the archaeological findings of the city of Tarragona, in conjunction with current cartography, integrated with Google Maps.
There are some applications available that provide information to the user on google maps, but not in the archaeological themes, http://www.onnyturf.com/subway/ provides the New York subway map and on http://www.nycgo.com/?event=view.maps users can see a tourist map of the same city. In our case we want to use the

technology to bring to the general public information about the Tarragona Romana and stimulate interest in this science.

2. SYSTEM DESCRIPTION

The application that is presented is focused in two slopes, first to have a base rigorous computer tool to store and process all the information related to archaeological actions done in a zone, and second as a tool to release some of this data to non-scientific community. The first one has led to a detailed study of the information to store in the database and to load previous shapefile data. The second one has resulted in defining an interaction with the information, attractive to non-expert users.

2.1 Specifications

All the information to store is around the archaeological sheet. This element covers all the information available of a specific area. Much of the information will come of archaeological actions done along the interventions, but it will be supplemented with news, historical references, and analysis results obtained from studying the information set. As shown in figure 1 all data provided by the old system are loaded on the project.

Figure 1: Shapefile data loaded on map of Tarragona

We will be storing both graphic and alphanumeric data for the archaeological sheet. In the first case we highlight which area occupies the field, which physical elements form it, where are located and what graphical representation they have: planimetric sketch of different elements. In the second case we emphasized about the different findings, descriptions that identify them, chronological period where they belong, constructive type that represents, level of protection of the zone by international agencies, among others.

2.2 Accessing the data

The application shows the user the combination of a typical map of Google Maps, with the available information on the database. The user interface is intended to guide the queries that the user can do. An example is shown at Figure 2. The information is divided in two zones: one with the map, at the left, and one with the controls to obtain information, on the right.

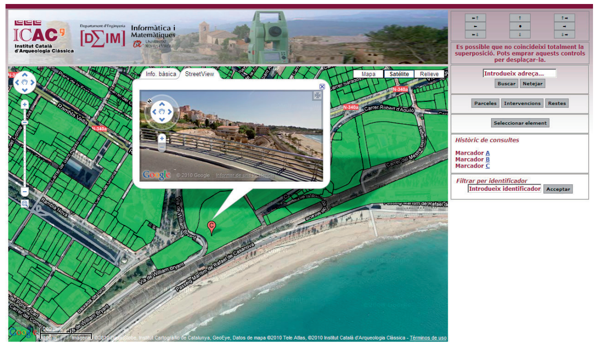

Figure 2: Integrating google and Tarraco data

Following the educational nature of the application we wanted to provide different types of searches closer to the people, like: what is under my house? How was Tarragona on a determined period? In the version presented we have advanced controls such as moving the map, enlarge a certain area with a magnifying glass that was added to the tools you already have Google Maps and in all cases to select an item. The information displayed is divided into layers and the interface itself has buttons to switch between them. It is simple. Besides the direct selection of an item on the map, there are basic queries available: check for address and see an item according to its identifier. The first causes the map moved to the indicated location and the second lets you view the selected item information, hiding the rest.
To provide usability, the cursor changes its shape if we are doing a query on the map or we are doing another operation. When an item is selected on the map, a typical information balloon from Google Maps is shown, with some tabs according to the type of the item we have selected, see Figure 3 for an example. The information on the balloon is loaded asynchronously, but usually this process takes less than one second. The system is prepared to stop the asynchronous load if a certain timeout is exceeded.

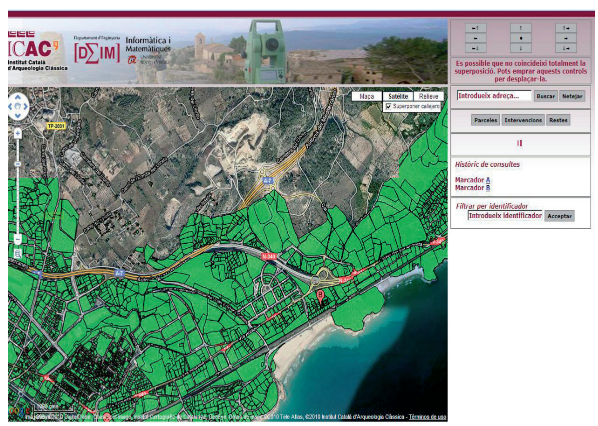

Figure 3: Displaying information with a balloon from Google

Also, a marker is added to the map and to a temporary history in the user interface, so we can track back the item if we change the location. Each marker has a letter associated from A to Z. Obviously, this fact limits the history to 27 items, althrough we can delete them at any time changing the active layer.

3. SYSTEM ARCHITECTURE

Described in this section is the set of tools chosen to develop the project. The main criterion has been to facilitate and optimize the access to the information. The second one is to build all the project with free technology.

The developed application consists of two parts, the server application which manages the database and provides information, and the client application based on web technology which provides an interface closer to the common user to access the information.

3.1 Technologies

To implement the database it has been chosen the PostgreSQL management system, with the geographical extension PostGIS, which unlike other database engines provides calculation and geographic query tools, and it is free software. The spatial data will be stored with the GEOMETRY type.

The server application has been implemented using Java technology, specifically J2EE. We have worked with Sun GlassFish as a application server, GeoServer as a GIS server, and GeoWebCache as a tool to cache the geographic data. All the tools work with the same programming language, providing code uniformity.

To generate the information on the server that the client will use, the following possibilities have been assessed:

- Serving the client the set of points. The client application would have to draw them with JavaScript, using some class like GPolygon on Google Maps API.
- Serving the client the map as a tile mosaic. Only PNG images.

We chose the second option for performance issues. In fact, the large data mapping systems use this option, like Google Maps or Bing Maps. The point is that we can't draw more than 400 or 500 polygons simultaneously without having huge slowdowns on the client's hardware. To generate the tiles we have used the Web Map Server tool from the GeoServer application.

The client application has been developed as a web application, separating the basic parts. HTML for the static part, JavaScript compression to save bandwith and load faster, AJAX to make dynamic content, and CSS to give appearance to the information.

3.2 Implementation

Figure 4 shows the structure of the server-side of the application. This leads to a very versatile design, allowing scalability in the future if the user base grows. The system is prepared to divide the services in different machines applying load balancing techniques.

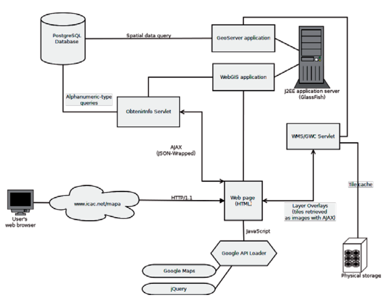

Figure 4: System architecture in the server side

Figure 5 shows the application structure on the client side. Althrough we are using dynamic web pages technology (J2EE), the basics are coded in a HTML file to lighten the application, since all users will be receiving the same initial map. As stated before, to improve load times we have used a technique to compress the JavaScript code executed on the client's web browser. This is used by some prestigious web 2.0 applications, among others Google Apps, Facebook, or Yahoo! Maps. There are several tools to compress the code available, the one used on this application is Google Closure Compiler.

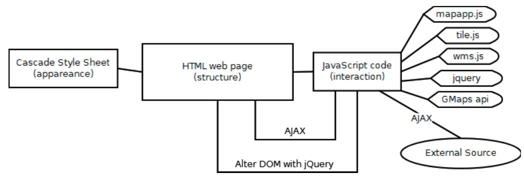

Figure 5: System architecture in the web side

The *Asynchronous JavaScript and XML* technology was introduced to manage background asynchronous *HTTP* requests, client-side. In a classical HTTP operation, the browser needs to reload the entire web page to see some changes. Using *AJAX*, we can invoke various background requests, and *JavaScript* code will modify the web page with the new content without reloading it.

Due to browser's diversity on the client side, we have decided to use a cross-platform AJAX function. This function is provided by the Google Maps API on the namespace GdownloadUrl. Google specifies that is implemented to support modern desktop web browsers and some mobile devices web browsers.

3.3 Adapting geographic data to Google system

The geographical data is stored in a Coordinate Reference System (CRS). To reference this systems, we use the European Petroleum Survey Group (EPSG) catalog. The initial data uses the ESPG:23031 system, which is focused only on Europe.

The problem presented was that Google Maps uses a different system: ESPG:900913. One of the goals of this system is to reference the entire world, having compatibility with the CRS of Google Earth and GPS devices. To accomplish this, Google works with geometric coordinates, a pair of latitude and longitude to locate any point on the Earth. Google Maps is a projected 2D map but it works with 3D coordinates.

At first we assessed applying a mapping reprojection to the initial data. We discarded it because it implies changing the format of all new data and updates provided by ICAC, that is to say, we did not want to change their system. The solution adopted is to bring that load to GeoServer, translated dynamically as tiles are requested to the Web Map Server. This decision may seem contradictory with the performance optimization criterion of the project, but in fact it is not. This is due to the map caching with GeoWebCache. We draw the tiles only once, and then they are sent to the client as prebuilt PNG files, saving CPU consumption.

4. EVALUATION OF THE SYSTEM

4.1 Transmittal

We have made an initial evaluation of the application at functional level, and performance tests of the server-side of the application as well of the client-side.
In the first case we have revised that the product provides solutions for the initial requirements. The server-side performance tests have been done with the NetBeans environment, a process viewer, and a Java Virtual Machine viewer. The tests revealed that at least, the server needs 1GB of memory to run. Of course the more users simultaneously, the more hardware needed on the server side.

- The PostgreSQL database needs at least 50MB of memory.
- The two web applications (*GeoServer* and *WebGIS*) take up to 1 minute to be deployed on the GlassFish server. This load-time is only needed once, when the server is booted up.
- The *GlassFish* memory consumption depends on the number of clients and the tiles to generate, but we can talk of a base consumption of 250MB of memory, having in mind the Java Virtual Machine.
- CPU consumption of both application is not quite high, althrough if we generate tiles "on demand" without using the tile cache it may raise considerably.

In the client application we have measured the memory consumption and the time taken to display the information. We have used the Firebug tool and we have run additional tests with the Opera web inspector (Opera Dragonfly). Variations between both browsers have been inappreciable.
We have studied the average load time with and without tile caching on a map of 3x3 tiles. Direct load takes up to 700 ms per tile, and cache load with GeoWebCache is less than 200 ms. This time difference can be negligible for the average user but, again, with a large amount of concurrent users or a slow connection it can be easily noticed, so we have decided to make the efficient choice.

5. CONCLUSIONS

We have designed an application that meets the project's goals. Studying the tools we have concluded:

- From the conducted research, we conclude that to make maps via web with large amounts of data, the best method is to use a tile mosaic.
- The best solution to store the information is with a geographic database.
- To widely spread the information, a good solution is to use the Google Maps API and provide an accessible map from any web browser.

From the work done in the project, some new ideas have emerged for future development, to extend functions or improve the application. The main idea is integrate the application with mobile devices. At present the mobile devices with Internet connection are very popular, and a possible development is to integrate the web application with this kind of devices.

Through version 3 of Google Maps API, we can make web maps fully compatible with devices such as *iPhone, Android or BlackBerry*. This provides a new experience for the user, who may query the map from anywhere.
Following the previous topic, we can make a practical use fo the *Google Location Services,* which allows to physically locate a user, always with user's consent, and give information around him.
For instance: a tourist is visiting the amphitheatre of Tarragona, and has an Android device with him. He does not need longer a sheet with the information of the monument, he can connect his phone to the Internet, locate himself with the application, and point at the map, receiving accurate information from the ICAC.
Another future development is integration with social networks (*Facebook* or *Twitter,* for instance). An application using the public API of this network with a practical goal: while the user is visiting at site some archaeological item or museum he can *tweet* it instantly in a easy way. This publication would include a link to the web map application, bringing new users to the application, a continuous feedback. The main advantage is to encourage more users to the application.

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FORMULATING DESIGN GUIDELINES FOR CULTURAL HERITAGE MULTIMEDIA SYSTEMS WITH BYZANTINE ART CONTENT

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KEY WORDS: Byzantine Art, Multimedia Design Guidelines, System Evaluation, User-Centred Design

ABSTRACT:
The development of future multimedia systems for the preservation and presentation of Byzantine art necessitates the formulation of special design guidelines, which brings Byzantine art and new technologies in a constructive technocultural symbiosis. The e-learning and pedagogical effectiveness of multimedia projects with Byzantine art content, the visualisation of Byzantine imagery, the deeper and devoted research in issues like the aesthetics of Byzantine art, the spiritual communication of Byzantine art promote the need of a technocultural approach synthesized by two "distinct" elements, multimedia and Byzantine art. With a proposed evaluation experiment for a website with a Byzantine theme, we investigate the reactions and perceptions of young people for Byzantine art, in order to create design guidelines applied on future projects with relevant content. The results of this survey evaluation study, targeting a group of Cypriot young people 15-30 age, superimpose the argument that multimedia e-learning projects specialising in Byzantine art, should promote design strategies that will enchase the communication of Byzantine art in new media.

1. INTRODUCTION

Multimedia information systems are being used in a large range of information dissemination applications in such fields as entertainment, education, healthcare, military-civil defence, tourism and cultural applications. According to the application domain, the design of a multimedia information system should address special issues related to the nature of the information presented but also the needs and abilities of the anticipated users. For this reason the design of successful multimedia information systems needs to be based on design guidelines derived through careful analysis of the needs of the target group (Shneiderman, 1998) in relation to the application domain. Due to its importance, the general topic of establishing guidelines that enable user-specific design guidelines for general applications, received considerable interest in the literature (Nielsen, 2000).

A special case of multimedia information systems are involved with applications that require concentration, spiritual involvement and deep engagement of the user in order to maximise the attractiveness of the application, maximizing in that way the educational impact and the level of spiritual interaction offered. Typical examples of such applications include multimedia systems for presenting artefacts and/or artefacts with symbolic meanings as part of information dissemination in cultural heritage applications. Such applications may require special design strategies so that the end result addresses the needs, abilities and expectations of the target users.

To the best of our knowledge, the formulation of customized design guidelines for multimedia applications that require the spiritual and emotional engagement of the user was not addressed in a systematic way so far. With our work we aim to derive design guidelines that can be used for developing multimedia systems for the preservation and presentation of Byzantine art, enabling the maximization of the user satisfaction in relation to the offered educational-aesthetic content.

As part of our work, we presented to a number of young volunteers the web site (www.culture.gr/mystras-edu) which contains information about Byzantine art and asked them to complete a number of tasks/scenarios that enabled them to experience different features of the system. The experience of the users was then evaluated through a customized questionnaire to determine key aspects of the system. The results obtained are analyzed and a set of design guidelines related to the development of multimedia systems for presenting and visualizing Byzantine art were derived from the results.

While many multimedia projects with archaeological and cultural heritage interest promote effective design practices that engage the potential users, we notice that multimedia projects specializing on Byzantine art, rarely promote the aesthetic and spiritual qualities of Byzantine art. We argue that the narrative potential of new technologies provides us the content creation tools for a successful aesthetic interpretation of Byzantine art and the effective engagement of perspective users. However the exigent factor for a success of such a system relies on a focused design, which especially applies design guidelines for multimedia design with Byzantine art content.

Our research indicates that the specific issue of formulating system design guidelines for the sector of Byzantine art has not been studied in the literature so far. On the other hand, HCI is a very important field of study towards the implementation of content oriented design guidelines. Accepting the principle that user engagement is depended upon the design of specific application (Nielsen, 2000) and usability based on age centred design (Zaphiris, 2005) · content oriented design also requires a careful understanding of the needs and abilities of users.

For justifying this argument we needed firstly to identify the background of young teenagers-adults on Byzantine art, and secondly to address their needs on using multimedia systems with Byzantine art content. Initially we directed our interest on a special age group of Cyprus population in order to derive design guidelines that reflect young age perceptions. The work described in this paper presents the initial stages of our ultimate task that involves the development of a multimedia information system for the narrative presentation and aesthetic communication of Byzantine artefacts. We are conceived that the presented design guidelines will be of utmost importance towards the development of a system that fulfils the expectations of the perspective users, contributing in that way to a more usable, enjoyable and effective distribution of information and knowledge related to Byzantine art content. Although our work is mainly dedicated towards the design of systems with a Byzantine theme, we anticipate that the end results and the proposed methodology will be applicable for the design of similar cultural heritage systems that require the spiritual engagement of the users.

The remainder of the paper is structured as follows: In section 2 a brief history of Byzantine art is presented. In Section 3 issues related to Byzantine art and multimedia are presented in order to justify the reasons that the design of relevant multimedia systems requires customized design principles. The methodology adopted, the results obtained and conclusions about our work are presented in sections 4, 5 and 6 respectively.

2. BYZANTINE ART

2.1 Historical Evolution

Substantially Byzantine art begins around 330 A.D. when the capital of Roman Empire is transported in Byzantium. Byzantine art from the catacombs time has been progressively shaped in a particular form of art with concrete characteristics and special formality. Initially samples of early art depictions adorned the catacombs with wall paintings that presented portraits of Saints, representations from the life of Christ, as well as symbolic representations. This special form of art evolved throughout the ages in the spirit of the church and tradition, accepting however exterior effects for example Hellenic naturalistic elements or even Egyptian art abstractive elements. Byzantine art was formed to its characteristic Byzantine image and language identity at the beginning of the 6th century (Popova, 2002).

After the Joustinian era (527-565), the early flourishing period of Byzantine art is followed by the Middle Byzantine period. The second flourishing art production period peeks during the Macedonian dynasty (867-1055) when Byzantine art has taken a more canonical form. From the middle of the eleventh century till the taking of Constantinople by Crusaders in 1204, Byzantium is ruled by the dynasties of the Comneni and Angeli. The Comnenian era leaves a special technotropy style in Byzantine art, the Comnenian style (Yuri, 2000). During the last dynasty of Byzantium the Palaeologan, lasting from the revival of Byzantine Empire in 1261 till the fall of Constantinople in 1453, Byzantine art underwent a renewed flourishing known as the “Palaeologan Renaissance”. Also in the Post Byzantine period Byzantine art is not extinguished but instead flourished in the island of Crete (with the famous Cretan school) and in many other Orthodox centres including Cyprus.

2.2 Theoretical foundation of Byzantine art

While Byzantine art “style” varied considerably during different periods the overall style remained stable. The various styles of Byzantine art are expressed through Byzantine aesthetic ideas determined by the Christian religious consciousness (Popova, 2002). In regards to Byzantine icon-painting the Byzantine image uses a particular language, which expresses irreproachably the doctrines and the commands of Orthodox Church. It is an art of spirituality which is expressed with the tools of painting without being just a painting. The Byzantine iconography- “Agiografia” portrays Saints in pictures, “writing” their narrative depicted Hagiographies.

In contrast to the naturalistic religious painting of the West a Byzantine image does not imitate absolute human physiognomies. Historical realities are rather expressed with perfect symbols in various Byzantine art compositions. While historical reality constitutes the most important question for the church, Byzantine art proposes a transcendental, exceeding the borders of time, revelation (Clement). These values apply in all traditional mediums of Byzantine art (icons, murals, mosaics, illuminated manuscripts, engravings, liturgical objects) and in Byzantine architecture. The religious and pedagogic extensions of Byzantine aesthetics are considered major cultural qualities of the theoretical foundation of Byzantine art (Michelis, 1967). Unfortunately these qualities are very often neglected by stakeholders of Byzantine art’s visual reproduction in new media.

3. BYZANTINE ART ON MULTIMEDIA

3.1 The problem on presenting Byzantine art in multimedia

In general, virtual heritage community faces a relevant critical question. This concerns the credibility and validity of disseminated cultural heritage information. Very often the documentation and validation methodologies applied are in question by professionals who have a stake in this field, for example archaeologists. Their expressed concerns raise questions on the reliability and the motivations behind many Virtual Archaeology projects (Ryan, 2001). The “spectacular” presentation of heritage material, in opposition to the archaeological consideration, is a basic argument for archaeologists who feel that virtual heritage is taking control out of their hands. For these reasons, even for the demanding field of 3d visualisations, newer approaches (Pletinckx, 2008) promote interpretation tools for heritage visualisations according to the requirements of the content.

But where the problem lies as far as Byzantine art heritage interpretation in multimedia is concerned? In regards to the internet presentation of Byzantine art, for plain reasons of ownership, museums holding Byzantine art heritage usually promote their artefacts and disseminate information of academic level in a limited way in the web. Also, this information is mainly intended for general public (Foskolou, 2007). In terms of Byzantine art aesthetics which is a subject equally important for pilgrims, Byzantine art students and specialist researchers, most usually church websites provide that kind of spiritual, cultural and academic content information (www.art.solidarity.gr/).

In recent VR (applications, scientists propose innovative imaging techniques for the 3d virtual reproduction of Byzantine monuments (http://byzantinecyprus.com/) and realistic computer graphic simulations for Byzantine art based on cultural heritage sites and objects environmental illuminations (Happa, 2009). But apart from the imaging innovations in Virtual Heritage the exploitation of spiritual cultural elements (faith, sacraments, rituals), based on the aesthetic approach to Byzantine art is rather rare in virtual environment design. While some researchers are interested in recreation of intangible cultural heritage elements (eg, dance, religious services, music), (Papagiannakis, 2002) the typical narrative potential of many works engage users in a virtual experience communicating mostly historical information (which in some cases might be

misleading). Virtual heritage research proposes many innovative methods eg, game design formulas and user evaluation techniques (Champion, 2003) to strengthen the agency artefact interaction, but still the interpretation of Byzantine art is a unique case which needs special treatment.
In most cases the spiritual cultural element in multimedia is proposed usually for entertaining the user rather as to present deeper cultural spiritual values (Lutz, 2001). The interpretation of deeper spiritual values which consists the essence of Byzantine imagery in most cases is not assisted in new media. Reliability for virtual heritage is a very important issue which concerns research on Byzantine art, an art which at the same time is so commonly known and unknown from the perspective of scientific circles. For this reason we have to identify the stakeholders who can be involved in the design of multimedia and virtual heritage projects with Byzantine art content and propose design special guidelines for this unique field.

3.2 Byzantine art on multimedia, a short review

In this section we describe four multimedia projects related to Byzantine art. These projects constitute good paradigms of study and evaluation towards the formation of general design guidelines for the unique case of Byzantine art.

3.2.1 Application CD-ROM COFIA, library of Byzantine history and art: Cofia (Cofia, 1994) was subsidised by European funds in the perspective of the work "SAPFO: Multimedia for education and civilization". The incompatibility of the software with modern hardware and software is the major disadvantage of the system, since the work COFIA was completed in 1994. The minimalistic design of the interface with simple hypertext links, subtle decorative design elements (Byzantine manuscript illumination), and the access to material of about 3500 illustrated book pages are the best provided features in our opinion. The site promotes a modest design which facilitates the navigation and sustains user attention. The learning material covers a large range of Byzantine content, which could potentially interest the general public but also dedicated Byzantine researchers.

3.2.2. Website-Cultural treasures of the Church of Greece: This work (www.art.solidarity.gr/) is a sponsored initiative for the creation of a digital collection for the cultural treasures of the Church of Greece. It contains a large collection of digital heritage about ecclesiastical history, art, architecture, literature, museums, music. It also includes a digital map and multimedia instructional material on "the presence of Christian temple". The website promotes the "dissemination of spiritual messages through the modern dialectics of information technology".

3.2.3 Web Application/Virtual tour-Byzantine museum of Archbishop Makarios III foundation:
The virtual tour in (http://www.makariosfoundation.org.cy/) (Kunkel, 2008), is a web application composed of connected spherical panoramas allowing the perspective user to explore the Byzantine Museum of Makarios III from inside the webpage of the foundation. The user can have an interactive communication with the application, choosing the panorama views of their choice. The main scope of the design of this work, with its panoramic visualisations of museum collections, is to create a presence feel in an immersive web environment which serves as incentive to visit the real place. The user has the capability to view the digitalized assets of Byzantine art (mainly icons) and get short descriptions for some of them.

3.2.4 Kastropolitia tou Mystra: The site (www.culture.gr/mystras-edu/) development was funded by European Union and sponsored by the Greek ministry of education. The Byzantine theme "Kastropolitia of Mystra" is about a unique castle- Byzantine state, which is the most well preserved Byzantine state in Greece. The organized structure of the website provides learning material that potentially might interest young children, the general public but even specialized researchers. The addition of instructions to teachers and adults for guiding 10-14 year old children proves the pedagogical, e-learning nature of this site. The website hosts important information for a place of local interest, a devastated Byzantine state of the 13th century. It contains also information on Byzantine art which we consider important for the proposed evaluation. The design of the webpage structures the content in a way to assist the viewer to navigate through, read information, view images and play also educational games.
Although there are good existing examples of multimedia systems presenting byzantine art, there is no established set of design or/and evaluation guidelines that can safely designers use and follow for establishing an effective, enjoyable and usable experience for young people. With our work we aim to define a set of design guidelines so that the dissemination of information related to Byzantine art is done in an effective way that satisfies the needs of the users.

4. METHODOLOGY

In this section we describe the methodology adopted in order to derive design guidelines for Byzantine art multimedia system development. From the beginning, the methodology plan was set to target a special age group, young population of ages between 15-30 years old to assist to a critical design stage, which is the evaluation of existing multimedia systems. The results of the evaluation were then used as the basis of formulating design guidelines. At this point we decided to exclude younger age children because they continuously shape their knowledge and perceptions on Byzantine art, while young teenagers-adults have a more crystallized personal view which we wanted to evaluate. Similar works of evaluations with young population were studied (Lucia, 2009), for different application domains, however we had to prepare an evaluation test to extract information on design which is content and site specific.

4.1 Case Study

The evaluation was done for the publicly available site "Kastropolitia of Mystra" site (www.culture.gr/mystras-edu/) that was presented in section 3.2. "Kastropolitia of Mystra" is an extensive webpage which can assist teachers as a school aid tool for additional educational material on topical history and Byzantine history material which is not included in the taught material. The design of a multimedia system with Byzantine art content is based on a Technological pedagogical content knowledge framework (Mishra, 2006) which eventually has a greater appeal on young age people. The chosen site was used as part of the evaluation procedure for the following reasons:

- The information on Byzantine art in a special part of the webpage and the overall design was suitable for our evaluation test.
- The overall design of the site (that incorporates instructions to teachers and adults for guiding children) proves the pedagogical, e-learning nature of this site.

4.2 Evaluation Stage

The group of volunteers who participated in the experiments included 9 males and 21 females whose mean age was 21 years (range, 15-30 years; standard deviation, 5 years). They were high school and university students, as well as young professionals with intermediate -very good acquaintance with computers and internet. The evaluation of the site was carried out with the supervised use of questionnaire with 15 questions focusing on the site design and four demographic questions. The questions were set in such a way, in order to derive information related to five distinct aspects of the system design: (a) The attractiveness of application, (b) the popularity of the Byzantine theme, (c) the quality of graphics and graphical details, (d) preferences regarding the media used and (e) the educational impact of the system. Typical examples of questions that aim to derive information for the sections raised above include:

(a) How do you think that most people will react after viewing the homepage of the site? (Answers: i) ignore the site, ii) Follow links for viewing icons, iii) Read text and view images in a certain link, iv) Read all information in home page)
(b) How interesting do you find the topic of Byzantine Art? (Answer: scale 1 to 4)
(c) Are you satisfied with the level of detail of the icons presented in the site? (Answer: scale 1 to 4)
(d) Do you think that the addition of audio and video in the site would enhance the experience? (Answer: scale 1 to 4)
(e) What type of educational material related to Byzantine artefacts you prefer to be presented in the site? (Answers: i) artistic style of Icons, ii) Symbolic meaning of Icons, iii) Historical facts related to icons, iv) All the above)

The time to complete the questionnaire spanned approximately for about 10-20 minutes for each participant. The order and the theme of questions was arranged in a manner of revealing participants understanding, and background on Byzantine art as well as their perception of Byzantine art in relation to the design of the special part of webpage under question. The scenario guided the participants to follow a certain navigation route within the web site, enabling in that way the evaluation of certain design elements of the site and its contents. Apart from answering the questionnaire, data related to key reactions, feelings and comments of the volunteers were recorded in a notebook by the administrator of the questionnaire. Such data reveals information that may not be extractable just through the questionnaire.

5. RESULTS

In this section we present the most important results derived through the analysis of the responses of the volunteers. The results-conclusions reported are based on results obtained through the questionnaire and the observation of the reactions of the volunteers. Based on the analysis of the results we formulate a set of key design guidelines that should be adopted for designing and/or evaluating similar applications. The results from the questionnaire are analyzed with respect to the demographics of the users and the five aspects (listed in section 4.2) of a multimedia system that we wish to evaluate:

5.1.1 Demographics: According to the results, the vast majority of the volunteers (86%) described themselves as religious so the results presented mainly refer to subjects with a religious background. Unfortunately the lack of samples with no relevant religious background limits the generalization ability of the conclusions-as part of our future work we aim to stage similar evaluation with users with varying religious backgrounds. As far as computer usage is concerned, more than 90% of the users stated that they have adequate computer skills. On average each volunteer uses the internet for about 3 hours per day. The most popular activities carried out using the internet listed in decreasing order are i) social networks, ii) educational activities, iii) job related activities, iv) computer games and v) on line-shopping. According to the results one can conclude that an important aspect of computing interests of the volunteers from the test group (and eventually the target audience) is social networking and educational activities. Therefore it is reasonable to assume that the combination of a Byzantine theme multimedia information system with an on-line environment suitable for supporting social networking and educational activities will have a positive impact on attracting users.

5.1.2 Byzantine theme: A strong tendency of associating a general Byzantine theme with art is recorded among the test group. Apart from art issues volunteers associated a Byzantine theme with emperors, religious issues and Byzantine literature. In contrast Byzantine icons are primarily seen as a way of expressing religious related actions and at a lower level as a means of obtaining information about the history of Saints that appear on Icons. This conclusion is not surprising given the central role of Icons in the Orthodox religion. Although the interest of the test group for sites with Byzantine theme was not rated as a top priority, adequate interest that justifies the creation of relevant information systems was recorded. The association of a Byzantine theme with art dictates the need for enhancing art-related issues within a relevant site.

5.1.3 Educational impact/Content: The educational impact of an application was clearly highlighted among the users as a key issue in relation with the success of a site. According to the results, more than 70% of the members of the participants expressed the view that multimedia-based education can be more efficient when compared or combined with traditional learning methods. In a different question the educational value of a site was rated among the most important features of multimedia information system. These responses lead to the conclusion that users of a site with Byzantine theme expect to receive knowledge during their visit to the site.
The need for an increased educational value of a relevant site is also highlighted by responses to questions related to the type of content that should be displayed in relation with Byzantine icons. 50% of the volunteers expressed their interest for a comprehensive metadata information presentation of icons and other Byzantine artefacts in multimedia systems. Such metadata should include the creator (many works of art are not signed), craft-Byzantine painting techniques applied, the lifecycle and history of the artefact but also symbolic and religious interpretation of Byzantine art which is very often neglected. In most sites that display Byzantine icons the content of the system usually includes only descriptions of digitized assets in regards to the title given, type and category, the place that is being kept and cited bibliography rather than providing the type of comprehensive metadata required by a significant proportion of the end users.

5.1.4 Attractiveness of application: Despite the fact that an adequate interest for a Byzantine theme was recorded, after viewing the home page of the site about half of the users indicated that they would had preferred not to carry on with the exploration of the web site. Along the same lines less than 50% of the volunteers found the home page of the site interesting. This observation leads to the conclusion that even in cases that the theme is interesting, an attractive web page is absolutely necessary so that users are encouraged to carry on with the navigation. In addition a strong view suggesting that the ease of navigation was a key issue in relation to the attractiveness of the system was recorded. Therefore standard HCI techniques need to be applied for this type of applications and on top of them design guidelines specific to the application domain need to be considered.

5.1.5 Quality of graphics: About 90% said that the quality of images of icons presented on the web site was acceptable. However, at the same time most users expressed a strong preference for viewing images with even better quality that enables the observation of fine details. This result is reasonable since in our earlier observations it was revealed that most volunteers associate a Byzantine theme with art hence a site with a relevant theme should present artefacts in a way that enables user to observe the artistic nature of icons.

5.1.6 Multimedia Support: 85% of the volunteers indicated that the use of other media other than still images and text, such as video and sound (that also implies narration) would enhance the overall experience. In addition more than half of the users have a positive attitude to the use of a VR system as a means of implementing information dissemination systems with Byzantine themes. Also the opinion that a VR implementation would enhance the overall spiritual engagement of users was expressed by more than half of the users.

5.2 Design Guideline Formulation

Based on the analysis of the results, it is possible to identify a set of important design guidelines that need to be taken into account during the implementation of a multimedia system for presenting Byzantine Art. The design guidelines defined are:

- Special attention is needed for a systems interface (in case of website, homepage).
- The system should provide effortless navigation through different sections.
- Design for knowledge gain (using reliable content from reliable academic sources) should be among the top priorities.
- Content-Treatment of different aspects (i.e. History, Byzantine aesthetics, religion, archaeology) should be treated individually or in a balanced way, to help the viewers absorb information.
- Images with art-content should be displayed at high resolution and so that users are able to observe details.
- Use of multiple media (images, text, sound, and video) is highly recommended.

Apart from the design guidelines quoted above the following recommendations were also derived:

- Designing immersive 3D virtual world is desirable, but questionable (the design of a virtual world will need a different design but many guidelines of these questionnaire might work as principles for immersive environments)
- Incorporating social networking elements (based on user's everyday activities) could form an attraction point.

Although there is evidence that these recommendations are important, their applicability needs to be substantiated through an evaluation of additional sites/systems that display the aforementioned characteristics. Additionally since the evaluated works mainly involve web content, special account will be given in line with existing guidelines for Web content eg Web Content Accessibility Guidelines (WCAG) 2.0 (http://www.w3.org/TR/2008/REC-WCAG20-20081211/) but also accessibility Guidelines for virtual world design which at the moment has not received the same level of attention as web accessibility (Tewirn, 2006).

6. DISCUSSION AND FUTURE WORK

A group of Cypriot young people 15-30 age, provided their perception and interpretation on Byzantine art, after navigating an educational website with a Byzantine theme, based on a questionnaire outlined scenario. The reported experiment enabled us to establish a set of design guidelines that designers can use for designing effective multimedia systems with Byzantine art content. Basic guidelines include the system interface design requirements, effortless navigation design, content specific design and use of special multimedia design recommendations.

The results of the study superimpose the argument that multimedia e-learning projects, specialising in Byzantine art, should promote design strategies that will enchase the communication of Byzantine art in new media. A main concern regarding the multimedia presentation of Byzantine art is the validation of Byzantine art based on Byzantine aesthetics, one of the main aspects of Byzantine culture and spirituality, which we consider very important. Apart from the real hosts of Byzantine art, nowadays technology allows the presentation of Byzantine art in the internet, multimedia and VR systems which very often results in the loss of cultural value during reproduction.

We realise that the disadvantages of virtual reproduction has effect on the "Aura" of artefacts and cultural heritage in general (Flynn, 2007) but some evidence from our evaluation show that proper presentation can protect the reproduced cultural values. For example some of the volunteers reported that two Byzantine images on the site caused them feelings of spiritual connection with the images even though the content of the page does not support such spiritual interaction (instead it provides general, mostly historic information). We believe that in Byzantine multimedia systems, the "Aura" of Byzantine art could be enhanced with special design that will promote content, aesthetics and social interaction. The multidisciplinary nature of this work requires special confrontation for which assistance from multimedia developers, HCI specialists, Byzantinologists, historians, theologians and system perspective users is considered very essential. For this reason we are planning to determinate the role of different expertises in the system development cycle and expand systems design research on Byzantine art. So far the on-study, target group experimental results enabled us to propose a set of valuable content-user centred design guidelines and establish a framework for future developmental design strategies.

However undertaking this research we faced some limitations. For example the small sample size (number of volunteers) does not enable large scale generalisation of the outcomes and statistical error-free conclusions. In addition the target group had more females than males and the participants had common religion. In the future we plan to address those issues by staging a similar evaluation study for a larger population group with demographic diversity, with participants of various ages-religions as part of an inclusive design study (Nicolle, 2001). The use of similar evaluation studies with various HCI guidelines can assist in deriving more standardized "know how" design strategies (Zaphiris, 2005). On the other hand, despite the relatively small sample size, the evaluation experiment gave us insight information that otherwise we could only hypothesize for, reliable results and content specific derived guidelines that researchers can employ in the development of future cultural heritage multimedia.

The current work is part of an ongoing work for the development of multimedia systems with Byzantine art content. We believe that more effective application-content specific systems will promote the better transmission of Cultural Heritage information, including spiritual aspects of cultural heritage. We anticipate that the end results of this study may be applied for different cultures with different religions and other intangible cultural heritage characteristics, where the user may establish a unique aesthetic relation with digitized artefacts presented in various multimedia systems. Through our work it was demonstrated that that a main aspect of designing cultural heritage multimedia systems is the critical phase of addressing evaluation-content specific practices at the beginning of system design. The outcome of these practices, a set of preliminary design guidelines, promotes the authentic reproduction of Byzantine art in multimedia.

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INTEGRAL VIRTUAL EXHIBITION FOR LITHUANIAN MUSEUMS

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ABSTRACT:

With the acceleration of digitization processes in Lithuanian museums and their growing number of digital collections the question of integrity and homogeneity of such content arise. The objective of the integral virtual exhibition portal of the Lithuanian integral information system is to unify the standards of collections descriptions and operational ontologies, and to widely represent digital content thus enriching European digital collections. This major goal was achieved with the establishment of integral virtual exhibition, a prototype of the prospective Lithuanian Integral Museum Information System that is now in a preliminary work stage. The exhibition defines the integral data model for the museum objects as well as the principles of the use of ontologies; it also describes the ways of presenting end-users with cultural content and sharing it with external portals. This paper aims at revealing the main principles the museums should consider in order to develop the Lithuanian integral virtual exhibition system.

1. INTRODUCTION

The processes of cultural heritage digitization have resulted in the increased amount of heterogeneous information. It thus presents considerable difficulties for information integrity, namely the interoperability, semantic relations and integration of heterogeneous content. Based on the Strategy on Digitization of Lithuanian Cultural Heritage, Digital Content Preservation and Access, the development of the Lithuanian Integral Museum Information System (LIMIS) has been initiated. The system would permit automated stocktaking of the museums' holdings, aggregation of museums databases into common repository, and finally, representation of preserved cultural heritage valuables integrally and worldwide. The cultural content provided by the museums is of heterogeneous nature which proves to be an obstacle for the end-users of that content. Moreover, it is not less of a challenge for a system to relate this kind of information. Technical compatibility between LIMIS and other related systems intended for data harvesting should be considered. Furthermore, the development of integrally preserved cultural content presentation application as well as the creation and use of ontologies, e.g. classifiers, vocabularies, keywords etc., should be taken into account.

Lithuanian integral virtual exhibition system provides an opportunity to publish digital content integrally and in a unified form. This semantic virtual exhibition describes integral data model and ontologies. It proposes the principles of digital content re-use and the presentation of exhibits descriptions for the end users. The present article, however, is not devoted to either the issue of stocktaking museums collections or the usage of data models related to these tasks. It rather proposes an approach to how represent and share main information about exhibits, and discusses the central principles that museums should apply in order to develop the national integrated museum information system. Furthermore, the article presents a homogeneous description schema for the digital exhibits. It is suitable for data gathering into the common virtual exhibitions repository as well as for data representation. These basic principles were adhered to while developing integral virtual exhibition system which is intended as a basis (prototype) for the prospective Lithuanian integral museums information system.

2. VIRTUAL EXHIBITION COMPONENTS

Cultural content is presented in diverse forms (documents, images, videos etc.) and is provided by different kinds of museums in heterogeneous form. It is available for both the public users and the experts, and is proposed by various independent memory institutions. The representation of heterogeneous cultural information is a challenge to organizations that provide content as well as to public users in the process of data finding and relating (Hyvönen, 2009).

Information system that collects contents from various data providers in homogeneous form can help solve these problems. Such public systems (portals) collecting cultural content from different sources and representing it in a unified form can be referred to as integral virtual exhibition system. Integral virtual exhibition is based on semantic web standards and unified methods for content description, i.e. metadata, ontologies, and rules. They are designed to improve structure, extensibility, usability, and user-friendly content presentation (Maedche, 2007; Reynolds, 2004; Hyvönen, 2009).

Integral virtual exhibition may result in creation and development of certain application solutions that will benefit public access users and content providers. Application solutions include:

- Aggregation of the distributed and heterogeneous content. Presented by various content providers, information about the exhibit can be compiled and made public through a single system, if it creates means to describe and preserve cultural content unanimously (Hyvönen, 2005);
- Semantic search. Using ontological content (classifiers, keywords, vocabularies etc.) and logic associations, the integrally collected cultural content provides the facility to realize a structured, integrated user-friendly search engine. (Pollitt, 1998);

- Unified navigation and content presentation. Cultural content in the virtual exhibition system allows the realization of semantic navigation system, cultural content presentation unification and standardization of content descriptions. There could be developed other intelligent services suitable for cultural heritage content, such as time-lines, personal collections, exhibits marking, commenting, ranking, etc. (Hyvönen, 2006);
- Automated content association. The items of cultural content created by different content providers but using the same ontological list of terms may be automatically associated with each other (for example, relevant exhibit can be reached pointing the same creation date or author);
- Cultural content reuse. Due to open semantic web standards the content of integral virtual exhibition can be reused in other web portals. Cultural content re-use implies a generalization of metadata in XML format (Känsälä, 2006; Mäkelä, 2007).

Hence, generally speaking, the integral virtual exhibition system should involve web services described above. First of all, what is needed is a common data model suitable for description of a wide range of museum exhibits, as well as ontologies (classifiers, thesauruses, dictionaries). Second, the system must provide content aggregation tool to collect museum exhibit descriptions that match the data model. Subsequently, cultural content environment - the user interface, which allows a unified search, navigation and content presentation - must be realized. And finally, there must be designed content render tools allowing the export of the content that is preserved in one database but may be used in other systems. According to the given nature of services that the integral virtual exhibition has to provide, the main components of such a system are presented (see Figure 1):

- Data model (metadata schema);
- Ontologies (classifiers, thesauruses, dictionaries);
- Cultural content (virtual exhibition services for the end-users);
- Data reuse (metadata exchange schema).

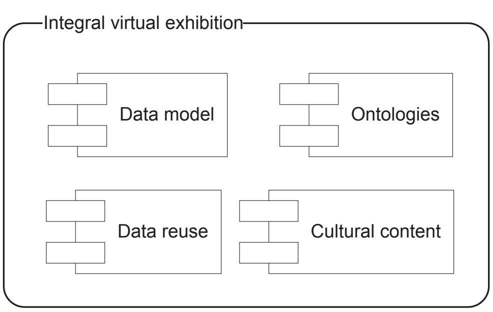

Figure 1: Components of integral virtual exhibition

Data model defines how, i.e. in what metadata, museum exhibits are described. *Ontologies* in virtual exhibition system describe vocabularies and concepts concerning real world and our conception of it. As much as modern web technologies enable, *cultural content* must be submitted to the end-user of virtual exhibition according to the data models and ontologies used. *Data reuse* enables virtual exhibition system to implement data exchange between the portals using XML files that contain single syntactic structure for the description of cultural object.

These are the fundamental components constituting semantic virtual exhibition that are commonly used in culture heritage systems (Hyvönen, 2006). The services, however, that virtual exhibition system offers - specifically, the provision of cultural content - could be expanded depending on the content and target groups of virtual exhibitions. For example, in semantic portals it is advised to apply semantic visualizations based on maps, time-lines, index of persons and geographic regions, integral search engine, unified browsing, unified content presentation, automated content association, etc. (Hyvönen, 2006).

3. LIMIS VIRTUAL EXHIBITION APPROACH

The development of LIMIS virtual exhibition system seeks to clearly define the integral model of museum exhibits descriptions as well as ontologies and their usage; it also specifies how to model the reusable content and what the ways of providing end-users with exhibit descriptions are. This prototype is being developed following the previously presented main components. It is designed not only for public users but also for museum employees as it will help them to prepare for the future LIMIS system.

3.1 Data Model

Data model of museum objects is usually described using metadata schemas. These schemas specify a set of obligatory and optional elements, i.e. properties, by which the metadata for content items should be described. For example, the Dublin Core (DC) Metadata Element Set lists 15 standardized elements. This set of elements can be extended by adding required set of extensions. As an example we could take the Europeana Semantic Elements (ESE) which consists of the Dublin Core (DC) metadata elements, a subset of the DC Terms and a set of twelve elements which were created to meet Europeana needs. The elements in the ESE are as follows: dc:title, dc:type, dcterms:spatial, dcterms:medium, europeana:unstored, europeana:country etc.; they are intended for museum objects description. Specifying data models suitable to characterize cultural heritage objects held in Lithuanian museums, such metadata description schemas as CDWA Lite, SPECTRUM or VRA may also be used.

The compatibility of integral virtual exhibitions system with other systems used in Lithuanian museums depends on what data model (metadata schemes) is applied to describe the exhibits. Metadata schema must specify the main exhibit fields that are used in most of the Lithuanian museums. The key fields of the exhibits are as follows:

1. museum;
2. collection;
3. primary account number;
4. inventory number;
5. digital image inventory number;
6. title;
7. type;
8. author;
9. creator;
10. creation date;
11. creation period;
12. place of creation;
13. finding place;

14. material;
15. technique;
16. measurements;
17. complexity;
18. subject;
19. description;
20. condition;
21. other information;
22. publisher;
23. publishing date;
24. rights;
25. digital image author;
26. digital image;
27. digital image description;
28. contributor.

The fact that exhibit attributes correspond to the fields in this list means that metadata schemes are syntactically consistent, regardless of which metadata scheme was taken as a basis of it. It is indeed a necessary condition for implementing a unified search of virtual exhibits and common navigation to full-text content. The distinguishing feature of interoperability of cultural heritage systems is whether they fit together the defined content metadata schema. If content metadata schema meets the DC metadata schema the exhibit descriptions of heterogeneous museum systems will generally accord with each other. However, DC attribute list should be expanded in order to provide more detailed description content. In our case, considering the key fields of the exhibits the best example is the ESE set of attributes. The minimum field list in the integral virtual exhibition system using the ESE attributes is as follows:

1. dc:title;
2. dc:type;
3. dc:contributor;
4. dc:identifier;
5. dc:creator;
6. dc:created;
7. dcterms:spatial;
8. dc:coverage;
9. dcterms:medium;
10. dcterms:extent;
11. dcterms:isPartOf;
12. dc:relation;
13. dc:subject;
14. dc:description;
15. europeana:unstored;
16. dc:publisher;
17. dc:rights;
18. europeana:isShownAt;
19. europeana:isShownBy.

Description of museum object corresponding to this data model can be gathered into the data repository of integral virtual exhibition system without any obstacle. The possible approach to harvest the cultural content into an integral database is the use of a specially designed (semi)automated tool for content aggregation or the use of protocols such as Open Access Initiative Protocol for Metadata Harvesting (OAI-PMH). This protocol can be used for publishing and harvesting the distributed content.
Cultural content aggregation system, e.g. virtual exhibition system, deals with metadata from heterogeneous databases that conform to a particular data model that was described above. Even if the content is heterogeneous, the described data model can be suitable to harvest data from other databases providing that metadata schemas used there are semantically interoperable. Therefore, the problem of interoperability between different metadata schemas lies in conceptual data models (ontologies). Such a standard ontology in the community of cultural heritage is the annotation ontology standard CIDOC CRM (Conceptual Reference Model) developed as an underlying schema into which, for interoperability purposes, other metadata schemas of the cultural domain can be transformed.

3.2 Ontologies

The data model specifies data fields but does not suggest what attribute values are required. Therefore, the choice of terms in certain fields of metadata schema must be determined by certain rules, i.e. a given potential list of values for certain attributes. These rules apply to dates, place names, persons, and other describing attributes. Data value lists have been specified by ontologies, traditionally known as vocabularies or thesauruses (Aitchison, 2000; Hyvönen, 2009). Such information filling approach provides a way to describe exhibits in a unified form both in heterogeneous and integral systems. The unified description of certain attributes in metadata schema is a key tool for the classification of exhibits, integral search and semantic browsing in the integral virtual exhibition system. In addition, the dictionary enables the development of complementary tools for navigation functions such as semantic visualizations based on maps, time-lines or index of persons. Therefore, the use of common ontologies in exhibit descriptions provides integrity and interoperability of data received from various sources.
Examples of cultural ontologies include the Thesaurus for Graphic Materials (TGM) for indexing pictorial materials, the Art & Architecture Thesaurus (AAT) for fine art, architecture, decorative arts, archival materials, and material culture, the Union List of Artist Names (ULAN), the Thesaurus of Geographic Names (TGN), etc. Lithuanian cultural heritage community recommended using the European dictionary (EUROVOC), the Library of Congress Subject Headings & Name Authority, the Universal Decimal Classification (UDC), and the Lithuanian bank of terms.
Virtual museum exhibits system provides 6 common ontology lists:

1. *Object types* that allow classification of objects according to their types;
2. *Place names*, enabling the classification of objects according to their creation, detection, restoration places;
3. *Person names*, enabling the classification of objects according to their creator, manufacturer, restorer etc;
4. *Periods (dates, ages, periods)*, which unanimously describes exhibits creation, detection etc. dates;
5. *List of materials* from which the exhibit is made;
6. *Museums* as content providers.

Additional ontologies for content description, such as condition, fund and language of description, can be proposed. The fundamental problem with the use of common ontology is that an ontology term in the vocabulary must be described before the exhibit is described. For example, if an object needs to be classified by a new term, the ontology list must be extended with this term, and subsequently, object description will then be corrected.

Ontology lists in each museum system must be taken from a centralized source, e.g. integral database, which is regularly updated. Hereby it ensures the integrity, unity and continuous updating of ontology by automated ontology data share in XML manner. The XML metadata schema for exhibits classifiers exchange consists of identifier, type of term and name. The principal scheme can be extended by a definition of a term, an author of a record, a sort number in the list and others. The same principle applies to data exchange schemas for keywords, names of persons and other ontologies.

3.3 Cultural Content

The goal of integral virtual exhibition system is to offer intelligent services for finding and browsing information in a unified form and in an easy way. Virtual exhibition system must provide users with clear and simple navigation, search engine and other services that modern web technologies enable. An important aspect of virtual exhibition is to develop the system in such a way that it will meet particular personal needs and interests that different users may have. Visitors of the museum portals seek information at various levels of detail as shown in Figure 2 and Figure 3.

Figure 2: The list of exhibits

Integral virtual exhibition involves specific services which include:

- *Integral search*. Easy, structured and multiple search engine based on data finding on metadata and ontology levels as well as semantic association of the objects.
- *Unified browsing and content presentation*. Unified browsing system expands search results by finding objects through associative links based on underlying metadata and ontologies. The conception behind such unified content presentation is to standardize digitized content to the end-user as well as propose other services such as time zones, personal collections, exhibits marking, commenting, voting, etc.
- *Automated content association*. Ontologically described cultural content submitted by different content providers may be automatically associated with each other, for example, by pointing to the same author or creation date.

Figure 3: The detailed description of an exhibit

Traditionally, information search is based on finding a word in a document. When performed on virtual museum exhibition system, the integral search is based on finding - on metadata and ontology levels - some features of the exhibits that are related to the search string. This type of search is in operation on web portals and is basically used for the search of non-textual information, such as an image. It is important for the content to have an appropriate description of special features, such as color, texture, etc. A similar principle is applied in the search of virtual exhibits attributes which are specified by the ontology and metadata.

The main problem of such a search is the mapping of search words to ontological terms letter for letter as entered by the user. The search query matches results only if the user entered a search word that literally meets the term in ontology list or metadata. The integral virtual exhibition should provide the end-users with an ontology list such as category index, category tree or category drop-down (Hyvönen, 2009). Thus, by selecting a category the related description can be retrieved. This type of search not only functions as a selection of results according to given criteria but also as a complex multiple search with custom criteria. It provides a possibility to choose the order in which results will be presented, as well as the logic conjugation of categories, etc.

Additional service to facilitate information retrieval and presentation in virtual exhibitions system is a unified browsing. Its main advantage is the ability to expand search results by appending them (by associative links) to other objects that are not related to the search word. A particular search result may be related to other exhibits by specific ontological relations. For instance, when several end-users identically mark the exhibits (subjective assignment of keywords) or the content provider assigns the same person name to different roles which in turn provides the users with an access to other objects (or collection).

3.4 Reuse of Cultural Content

The content of integral virtual exhibition may be reused in other external information systems due to open web standards suitable for cultural content. Cultural content reuse implies gathering and merging information contained in XML files but received from different sources. Such content must be rendered from external information systems regardless of different XML syntactic structures, i.e. the content should be integrated without losing data. The LIMIS virtual exhibition prototype allows to provide collected content using Europeana Semantic

Elements which consist of DC metadata elements, a subset of the DC Terms and a set of additional elements.

The Metadata Encoding and Transmission Standard (METS) is used to encode and provide data to external information systems. Cultural content is encoded using METS standard package where the exhibit-related information and links to digital image files, as well as a link to original complete description of an exhibit is provided. The example of an object description in METS format as it was adopted for the objects of virtual exhibition is given in Figure 4. A METS document consists of seven major sections. The virtual exhibition system uses four of METS standard sections:

1. METS Header,
2. Descriptive Metadata,
3. File Section,
4. Structural Map.

```
<dmdSec ID="DMD01" STATUS="FULL">
    <mdWrap MIMETYPE="text/xml" MDTYPE="ESE" LABEL="Prieverpstė (prie
        <xmlData>
            <europeana:type>TEXT</europeana:type>
            <dc:format>text/xml</dc:format>
            <dc:language>LT</dc:language>
            <europeana:hasObject>True</europeana:hasObject>
            <dc:title xml:lang="lt">Prieverpstė (prievartė) su smeigt
            <dc:type xml:lang="lt">Etnografinis eksponatas</dc:type>
            <dc:contributor xml:lang="lt">Lietuvos dailės muziejus</d
            <dc:identifier xml:lang="lt">LDM LM 1101/1</dc:identifier
            <dc:creator xml:lang="lt">Mažonas Juozas</dc:creator>
            <dc:created xml:lang="lt">Apie 1935 m.</dc:created>
            <dcterms:spatial xml:lang="lt">Skuodo rajono Notėnų apyli
            <dc:coverage xml:lang="lt"></dc:coverage>
            <dcterms:medium xml:lang="lt">Medis</dcterms:medium>
            <dcterms:extent xml:lang="lt">h 31,5 cm</dcterms:extent>
            <dcterms:isPartOf xml:lang="lt">Lietuvių liaudies menas</
            <dc:relation xml:lang="lt"></dc:relation>
            <dc:subject xml:lang="lt"></dc:subject>
            <dc:description xml:lang="lt">Apie 1935 m. liaudies meist
            <europeana:unstored xml:lang="lt">Kūrinys eksponuotas 200
            <dc:publisher xml:lang="lt">Irena Ūdraitė</dc:publisher>
            <dc:rights xml:lang="lt">Lietuvos dailės muziejus</dc:rig
            <europeana:isShownAt>***nuoroda i pilna aprasyma***</euro
            <europeana:isShownBy>http://www.muziejai.lt/emuziejai/Upl
        </xmlData>
    </mdWrap>
</dmdSec>
```

Figure 4: The exhibit description in METS

METS Header contains metadata describing a METS document itself, including such information as creator, editor, etc. Descriptive metadata section contains internally embedded descriptive metadata. File section lists all files containing content that comprise the electronic versions of a digital object. The structural map is the heart of a METS document. It outlines hierarchical structure for a digital library object and links the elements of that structure to content files and metadata that pertain to each element. The cultural content provided in such a way may be gathered by other information systems. It is possible to do not only when there is a direct link to the virtual exhibition but also when there is a lack of connection and data is delivered in various media (Varnienė-Janssen, 2009).

The metadata encoding schema presented above is just one of the possible schemas for cultural content reuse. This metadata schema for data sharing has been chosen for Europeana portal via Athena project aggregator. This pattern, however, can be used in many other external systems corresponding to ESE or having the ability to aggregate content regardless of different syntactic structures in XML files.

3.5 Data Provision

The cultural content of the virtual exhibition system initiated by the Lithuanian Art Museum (LAM) can be accessed at Europeana - the European digital cultural heritage portal. LAM has become a partner of Athena project, hereby facilitating the provision of content to Europeana using the proposed specific exhibit metadata schema. The data provision function is part of integral virtual exhibition system. It uses this schema for data sharing independently of a content provider.

```
<lido:objectIdentificationWrap>
  <lido:titleWrap>
    <lido:titleSet>
      <lido:appellationValue>Prieverpste (prievarte) su smeigtuku</l
    </lido:titleSet>
  </lido:titleWrap>
  <lido:repositoryWrap>
    <lido:repositorySet>
      <lido:workID lido:type="local (default)">LDM LM 1101/1</lido:w
      <lido:repositoryLocation>
        <lido:namePlaceSet>
          <lido:appellationValue>Lietuvos dailes muziejus</lido:appe
        </lido:namePlaceSet>
      </lido:repositoryLocation>
    </lido:repositorySet>
  </lido:repositoryWrap>
  <lido:objectDescriptionWrap>
    <lido:objectDescriptionSet>
      <lido:descriptiveNoteValue>  Prieverpstes šonai profiliuoti, p
    </lido:objectDescriptionSet>
  </lido:objectDescriptionWrap>
  <lido:objectMeasurementsWrap>
    <lido:objectMeasurementsSet>
      <lido:displayObjectMeasurements>h 31,5 cm</lido:displayObjectM
    </lido:objectMeasurementsSet>
  </lido:objectMeasurementsWrap>
</lido:objectIdentificationWrap>
```

Figure 5: The fragment of LIDO metadata schema

The provision of cultural content metadata for one of the possible external systems (which in this case is Athena - an aggregator that helps museums bring their content to Europeana) was carried out in accordance with metadata description format that is given in Figure 4. The "Athena Ingestion Tool" developed by National Technical University of Athens is used for content integration. This tool may be characterized by its principle of integration of different standards and harvesting formats simultaneously focusing on semantic interoperability. The aggregation of content from other sources can be performed regardless of metadata schema used. Athena Ingestion Tool opens up a possibility to directly import into the system, i.e. to map metadata to the LIDO (Light Information for Describing Objects) schema which is based on CIDOC CRM. The LIDO schema fragment that matches LIMIS virtual exhibition metadata schema is presented in Figure 5.

4. CONCLUSIONS

In this paper the integral virtual exhibition system for Lithuanian museums was presented. Integrally and in a simple way, the system collects heterogeneous cultural content provided by Lithuanian museums at the same time ensuring all the basic functions of such systems.

Integral virtual exhibition system involves basic web services enabling users of cultural heritage portal to browse and find the preserved content in a unified form. The system is based on semantic web standards and requirements for the metadata of cultural content. This paper specifies data model, ontologies, data reuse principles and ways of presenting cultural content all of which are necessary to improve the structure, extensibility, customization and usability of the system. The components of

integral virtual exhibition system presented in this paper are the essential conditions for providing modern services and ensuring cultural content reuse. In addition, the paper presented the content reuse method that was practically tested.
Virtual exhibition system has recently been introduced to Lithuanian museums getting them ready for the future LIMIS system. LIMIS will provide ampler opportunities: stocktaking of the museum exhibits, exhibits reporting system, multiple user interface, homogeneous system of classifiers and thesauruses, data archiving. The still developing virtual exhibition that is a prototype of the prospective LIMIS system will help to achieve the below listed goals that LIMIS is working towards:

- gather, process, preserve and share information about national holdings of Lithuanian museums integrally,
- make information about cumulative national holdings of Lithuanian museums more accessible,
- promote researches of the Lithuanian cultural heritage,
- enrich Europe's cultural and scientific resources.

This is the agenda for the next two years.

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DIGITAL PRESERVATION OF INTANGIBLE CULTURAL HERITAGE: SHARING THE "RITES OF PASSAGE" THROUGH A PUBLIC PRE-K – 12 EDUCATION EXPERIENCE

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KEY WORDS: K-12 Education, Intangible Cultural Heritage, Digital Preservation, Rites of Passage

ABSTRACT:

Intangible Cultural Heritage (ICH) can be difficult to conceptualize for American adolescent students. The benefit of ICH in formal education is underutilized in our school. The aim of this project highlights ICH in individual students' lives both at home and at school. Adolescent rites of passage are keystones in the foundation of their identity. It is in the recognition and understanding of the students' personal ICH identity that we can foster and evoke connections between the multitude of customs and traditions in our school community. Validating adolescent experiences with ICH and through extension, Cultural Heritage, students see themselves in contemporary context and are primed to participate in a global conversation. The testimonial in this project is the digital documentation of Intangible Cultural Heritage and the export of that student body of work to others.

1. INTRODUCTION

1.1 The Ogden International School of Chicago

"Every view of the world that becomes extinct, every culture that disappears, diminishes a possibility of life." -- Octavio Paz

Ogden School was founded in the nascent history of Chicago opening its doors as Public School #10 in 1857. Devastatingly impacted by the Great Chicago Fire, equally affected by two world wars, and now experiencing the most rapid transformation in its one hundred and fifty-three years as a public school, Ogden has physically and ideologically evolved into Chicago's first Pre K-12 public educational institution. Ogden has forged a foundation built on international education. Partnering with the Asia Society and The International Baccalaureate Organization, Ogden has formed a triad that holds at its core a global focus and commitment in educating our students for the 21st century. On an American timeline, Ogden is both old and new; traditions of the past now mix with different experiences brought to our classrooms from every continent. The diversity of our city is represented in our school population. More than forty world languages are spoken in the homes of Ogden students. It's this storied past, the rich cultural diversity and the exponential trajectory of growth that provides the platform from which Intangible Cultural Heritage (ICH) can be explored.

2. THE IMPORTANCE OF INTANGIBLE CULTURAL HERITAGE IN EDUCATION

In a typical classroom, cultural heritage by itself can be tangibly addressed. A history teacher can compare and contrast the Roman Coliseum and its gladiators to Soldier Field and the Chicago Bears (American football). These physical structures can be studied, materials can be compared and styles of architecture can be discussed and debated. Through technology, these tangibles are easily accessed, digital models can be constructed as well as virtually visited, and an actual learning experience can evolve. Less visible, but equally important, is ICH, particularly in a diverse urban landscape such as Chicago. As educators, we believe that ICH plays a critical role in connecting the "was" to the "now" and creating the "will" be. In public education, ICH creates a new important focus, explaining and validating current rites of passage. This revelation is critical. Students often see themselves disassociated from their education as if it is happening "to" them. Students see their cultural heritage as static and unchanging. We know this is not the case. The goal of this short paper and subsequent digital documentation is an effort to connect students to their past and their contemporary rites of passage. All of our students have traditions, many of them dissimilar to perceived de facto European/American heritage. It is in this exploration and documentation of these differences and the fact that the traditions are alive, are practiced and then shared with their peers that ultimately, students feel validated, see the similarities in their respective ICH, and benefit immeasurably.

ICH as it is, in the day-to-day rituals of our school culture, structures a figurative scaffold that supports and directs our students' school lives. Students and teachers are interacting with their ICH every day. From the anticipation of an upcoming event, Thanksgiving, their imminent ACTs, or their hopeful graduation, each step along their way is influenced by their respective ICH. By understanding the similarities and differences surrounding rites of passage, holidays, religious ceremonies or sporting events, our students begin to develop a sense of identity, responsibility and a social cohesion making them feel part of a burgeoning school culture. A goal is to foster cultural responsibility and respect, beginning at school and spiralling out into every aspect of a student's social network.

3. EXPOSURE OF INTANGIBLE CULTURAL HERITAGE TO STUDENTS

All too often Cultural Heritage is reduced to material things (artifacts in a glass case), events (an Independence Day celebration), collections (museum exhibitions) and categories (Native American Art). Cultural Heritage encompasses many of those components but cannot be represented in or by one term or item. We feel that Cultural Heritage has a reflective, individual quality and is a way of defining ones' self that can be qualified as a way of thinking about identity and roles in the context of the communities one belongs to. Intangible Cultural Heritage study becomes critical when looking at multicultural communities, clearly the case in the USA. Cultural milestones, rites of passage and examples of personal ICH as it applies to the family history are eminent and important. In these authors' opinions the USA, as opposed to many European countries, defines itself as a nation state with a mixed race identity. Our definition of an American is more a way of thinking about, living in, and viewing the world.

Ogden International students are already experiencing intangible cultural heritage, they just don't necessarily recognize it. Familiar rites of passage in American high schools include, but are not limited to, Coming-Up Ceremonies, Homecoming Dance, obtaining a driver's licence, registering to vote, Senior Prom and graduation. These are typical milestones in an American high school. Yet, as we absorb elements from other cultures, we experience their individual rites of passages from their extended ICH. Chicago students with European ancestry have the privilege to attend a peer's Quinceañeras, or a Bat/Bar Mitzvah. Students of Southeast Asian ancestry can participate in national holiday which has little to no connection to their original homeland, yet these holidays provide a sense of cultural cohesion to their newly adopted country. Students move through these moments often subconsciously, not always seeing the connection between the identity of their high school culture and themselves.

4. CONNECTING WITH SISTER SCHOOLS: COMMUNITIES OUTSIDE OUR OWN

Ogden International takes seriously its International Sister City/Sister School Partnerships. We have taken almost six years to create them: they were carefully vetted, clearly beneficial on both ends and official (signed by both City governments). Students in grade 6-9 are exposed to visiting school groups from abroad. Many students (65 in 2009-2010) hosted a student from one of our Sister Schools. All Ogden students have the opportunity to travel internationally as part of their official studies. The school offers four distinct field experiences, which are in themselves a true mosaic of cultural heritage, and intangible cultural heritage experiences. Mexican folklore, Serbian festivals and French culinary indulgences are only a few examples of what Ogden students do when studying abroad. All field experiences require a home stay component, where students spend time living with a family from that country. Inevitably this leads to many informal ICH opportunities: from interactions with an elderly relative to a sub-culture tradition based on a national holiday. Students also participate in hands-on cultural heritage activities such as creating pottery dyes from plants or mixing the ingredients for various chocolate products at a true "*chocolatier*". Documenting these experiences to bring back and share out with families, fellow students, and Ogden faculty take many forms. Most prominent and promising are digital photographs/video. Students also will Skype or video conference with their classmates, albeit from a more traditional setting (classroom or university). CH and ICH experiences are also shared out via the school newspaper *The Ogden Times*, or on a teacher's website. Additionally, we have called together grade level assemblies to share live student testimonial and photo narratives bringing the message to all students. At Ogden we strongly believe that students need to be connected to the wider world and that personal experience is quintessential for them. What young adults recognize and connect to, they begin to care about; from there we can hope to nurture that growing concern/understanding into the desire to seek out and preserve CH and ICH.

To our knowledge and disappointment, we have not found any other school that is initiating this type of study. However, we do know of Chicago schools and their international counterparts that engage in digital documentation around language acquisition and home stay hosting of foreign students. Yet, none of these schools come near to the complexity and the recognition of ICH in their lives. Granted, many of these schools have outstanding programs devoted to CH, yet the innate intangibles that are being experienced are not necessarily celebrated. It is our aim to embrace the importance of these intangibles and to showcase and share them both to our community and our sister schools.

5. ELECTRONIC DOCUMENTATION

The electronic documentation process follows a logical timeline. Students first create electronic portfolio entries, i.e., digital photographs, videos, digitally scanned artifacts and personal narratives that show specific examples of their personal ICH as it applies to their family history. The body of individual student work can be delivered as a website, a DVD/CD-ROM presentation, a PowerPoint, blog, e-story telling entry or as a digital storyboard. Portfolios develop as students move through the grades. Specific projects or requirements will be showcased according to grade bands. Ideally, students should use a combination of media and presentation instruments to reach their widest audience.

Archiving the projects is an essential component that necessitates a predetermined strategy. Digital media is prone to deterioration, unintended erasure, weather, fire and a myriad of other catastrophes that can occur. DVD discs cannot escape entropy. Therefore, all of the project documentations should be housed on a centralized server located in the school building itself. Certainly DVD discs can be made for distribution, but the mainstay of the collection will be collected on the server. At the onset and periodically after-the-fact, the documentations should be backed up on an external hard-drive that will be stored in an offsite location. Every 3-5 years, the media will be migrated to a newer hard-drive both on the server and the external. By housing the projects on the school server that also hosts our school's website, we will be able to metatag the projects and create a searchable database that will allow complete Internet access to the archives.

6. OGDEN ACTION PLAN

Fundamentally, action begins with recognizing and teaching the importance of ICH in students' personal lives. Prompting students to appreciate the "now," the immediacy of ICH in their upcoming rites of passage and festivals, constructs a new interwoven identity. The success of the process requires students to stretch their lens as they look beyond their sphere and delve into the lives of others in their community. Extending that concept further, students look outside to countries with vastly different ICH definitions.

Inevitably, teaching the technology and skill sets of digitalizing these myriad of experiences comes into play. We will need to provide the students with the materials to record and capture their events, their artifacts, the sounds of their daily lives and to collate them into a cohesive, organized product. As stated before, students will share these portfolios through a centralized school-based server allowing access to all of their products through the Internet. Archived portfolios will be used as digital evidence of ICH which we anticipated will change over time. As the archive grows, so will the diversity of examples and their uses. We plan on sharing these portfolios digitally with our Sister Schools and will digitally document ICH school experiences through similar media and technologies. Also, students will reflect on the learning surrounding their studies and international experiences, either personal or through the school with a focus on global ICH.

As a learning community is organized in concentric ring format, one can see family first, school second, neighbourhood next, followed by our city, then to the outermost goal of global consciousness. The resulting digital portfolio can be shared with: matriculating students, with other Chicago Public Schools, as part of their college application process and as their Year 5 Personal Project (Middle Years Program). Additionally, students could consider using their digital evidence in sophomore research classes or as part of their senior thesis.

7. EXAMPLE PROJECT

Embedded in our International Studies course, which all 6th through 10th graders take, we devote approximately one semester on cultural heritage. As students become more fluent in the vocabulary, experiences, and the gathering of information about Cultural Heritage, we expand the curriculum to include ICH and require digital documentation. To a certain degree, the semesters themselves are a mix of understanding the hardware, the software and the process of creating a digital chapter. The following is an abbreviated example of a 10th grade capstone project which incorporates the knowledge gained around CH and ICH, the use of digital media to capture and deliver the experience to an anticipated international audience.

"School discussions around CH and ICH have resulted in an interesting student directed assignment: Find and document (electronically) an ICH milestone/rite of passage event that highlights an aspect of your culture (remember students in a multicultural community like Chicago your "milestone" may connect between several cultures or combine milestones from several cultures). This documentary will be shared out at the school level and pushed out electronically to one of our Sister City World Schools."

16 year-old Travis decides to document the coming of age rite of passage of obtaining his driver's license. He did not wake up on his 16th birthday and have this handed to him. He had to take and pass a driver's education course offered at our school, participate in driver simulations and a paper test. He also had to obtain a learner's permit, a behind the wheel course with an instructor, 100 hours with an adult, and road test. Once he passed each hoop and hurdle, his life gained a new sense of independence.

Why is obtaining a drivers license an American "rite of passage"? We live in an expansive country with lots of space. Not everyone lives in an urban environment with public transportation available. In fact, the suburban American culture was born out of the car and all its trappings. Although not every teen has a car, the vast majority of teens get a license. Obtaining that license is the first step in the "what comes next" in adult life. In this rite of passage, a newly acquired independence is found. Newer responsibilities arise as Travis enters the car culture. He has to think about getting a job to get some cash to buy his first car, then making it street legal by purchasing the registration, the plates and the insurance. Going through this process of earning his license in effect duplicates as a microcosm, the steps, procedures and sequential ordering of adult life and careful planning. As a rite of passage, this works quite well and has a clear educational component to it.

All of this can be documented in a variety of ways. Through pictures, video and scans of the documents that he procures along the way, Travis can collect and arrange all these pieces and put together a digital narrative of his choice to present, celebrate and to later reflect on. Now, this may be repetitive to most if not all of his classmates, but perhaps to a class of students in a foreign country that is not so car cultured the impact would be greater and provides a window into teen American life that is rarely portrayed by the American media, yet has such an impact on our students' emerging adult lives.

8. CONCLUSION

Like the Roman god Janus looking back and forth in time simultaneously, Ogden School has the privilege of being both old and new, mixing traditions of the past with the promise of the future. Partnering with the Asia Society and the International Baccalaureate Organization avails us to inculcate in our students a sense of global ownership while recognizing their individuality. Diversity in both ethnic and socio-economic households of our student population provides the raw materials for us to build an understanding and appreciation of ICH and CH. As educators, we concur that ICH plays a critical role in the daily lives of students. Rites of passage, organized through school or a product of the home, provide documentable milestones, tangible and important in student life. Students will witness the *intercultural* and *intra-cultural* connectedness of these momentous occasions. As an international school with deep Sister School partnerships, Ogden makes easy and accessible opportunities for global familiarization. In travel, through foreign exchange student hosting and through digital dialogue, we bring the classroom to the world and the world to the classroom. Documenting intangible cultural heritage of the Ogden collective utilizing current technology allows our educational community unfettered insight and access to our archives. The value of the digital archive is immeasurable, it provides a concave lens into our own students' lives and traditions; this expanded view, widens their perspective, elevates their awareness, and is a permanent record of their and their peers' human condition.

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IMAGE BASED RECORDING SYSTEM FOR THE DOCUMENTATION OF BUILT HERITAGE

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KEY WORDS: Built Heritage, Architectural Conservation, Restoration and Preservation Planning, Building Archaeology, Historical Architecture, Metadata, Digital Documentation, Image tagging and keywording, Historic Preservation, Latvia

ABSTRACT:

Designing for building conservation involves the review, analysis and comparison of a large amount of visual information. By the process of file organisation it is possible to select the necessary files and to extract the information in a quick and easy way. Without the need of specific database or external records, the properly tagged image files themselves carry all the necessary information. This paper explores the requirements and looks at the possibilities of creating the necessary provisions for an image based architectural heritage recording system, the results of which can be linked to existing online cultural heritage databases (e.g. Europeana) or eventually included into the digital photobank of the World Digital Library initiative.

1. INTRODUCTION

Image is the most powerful tool for communication whether it be for design ideas, documentation of the existing state, or just various architectural features. The process of design and decision making in architectural conservation is primarily based on the processing of information. Besides archive documents, building conservation also involves work with such visual materials as photo fixation of the structures prior to the works, progress reports and post conservation records.

Figure 1: Various types of images in architectural conservation - from archive manuscripts, historic drawings, design documents to numerous modern photos

This results in huge number of digital photos, which contain not only valuable data on the existing state of the monuments, but which can also serve as a reference and provide useful tips for further works. Within the field of architectural conservation, several basic image types can be distinguished (Figure 1):

- archive documents - historic plans, projects, drawings, sketches, photographs, artworks, etc.
- site photographs - documentation of the current state, ongoing works, as-built fixation,
- travel photographs - a kind of digital sketchbook with similar or typical historic elements, architectural details, modern approaches, design solution etc.

In order to provide the background for motivated decisions governing the planned interventions and activities of stabilisation, a definite system for organizing the images is necessary. By reviewing historical views and comparing them to the modern situation, it is possible to recognize not only the former rebuilding activities, but also determine the extent of the decay or judge the effectiveness of previous conservation works. In the case of lost building parts, finding and analysing items of similar age, author or location can provide a basis for reconstruction and reinstatement. It can also help to understand the original planning or spatial concepts as well as lead to further theoretical research. In order to quickly resolve the required visual information a definitive method for effective organization of images is necessary

2. METADATA IN IMAGES

As at any other case when large amounts of data have to be processed, computer based systems prove to be the most effective tool, which have superseded the paper based filing systems. Currently textual or numeric information can be searched for by any keywords, phrases or figures in a simple and effective way.

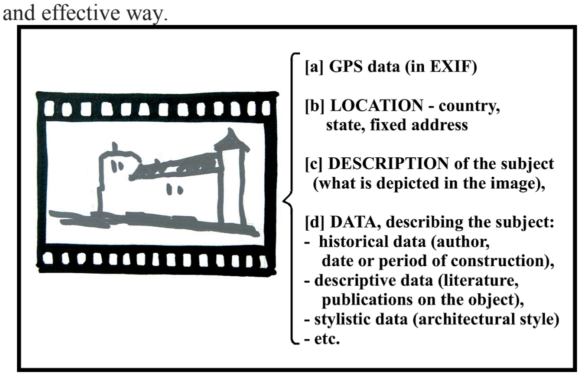

Figure 2: Various types of metadata, stored in an image file

The search of visual information is rather limited - the so called content based image retrieval systems are still under development (Lew M., 2006). However promising the research work is, at present there are no reliable methods of direct image - content based querying or systematization (Wikipedia, 2010). In the field of conservation one of the successful and perspective projects has been carried out by GREC group in St. Petersburgh (GREC group, 2010), where characteristic colours of stone are used to automatically recognize similar details wherever the item is located. Development of such systems and the widening of their use will definitely succeed in the near future.
Image databases used in the cultural heritage management are text and description based. However the standards of the description vary among the institutions, and the descriptions themselves tend to get outdated over the time. The programs, used to create and manage the databases, when updated, do not always provide sufficient backward compatibility. In order to systematize the image files, instead of creating separate database files definite textual information can to be stored in the image itself. The approach discussed below concentrates on the possibilities of containing all the additional information in the form of metadata within the image file. Thus the drawbacks of the text based systems are eliminated, allowing different approaches and usage of various programs for information retrieval.
Besides the technical information on the shooting conditions (being included in EXIF or Exchangeable Image File Format), image file can also include other metadata (see Figure 2). The proposed application eases the process of adding to this additional information.

3. WORKING SAMPLES

There are several ways of storing the metadata within an image file. The most accessible way is to use the file name, which, e.g. under Windows XP, can be up to 255 characters long and can contain definite amount of information. However the standard file manager cannot be considered a comfortable tool for image renaming, which will be discussed further below. Yet the length of the file name allows for rather inclusive description of the subject, depicted in an image file.
Besides the file name, the "hidden" information can be embedded into the file. News agencies, journalists and reporters extensively use captions and photo headlines stored according to the IPTC (International Press Telecommunications Council) Photo Metadata standard (ICTP, 2010). Alternately XMP (Extensible Metadata Platform) standard has been developed and is claimed to be compatible with IPTC (Adobe, 2010). The experience in tagging, gained since 1990s, provides a strong background for image tagging in the conservation field.
The good workflow for image retrieval can be illustrated by online search engines. In everyday practice, the internet is of invaluable help for up-to-date data - e.g. in the field of architecture it is possible to find suppliers and technical specifications on almost any design item, whether it would be a door, a wall panel, roof covering etc. A similar service for historic items, where currently the data in most cases is unsatisfactory, sketchy and inaccurate, is of crucial importance.

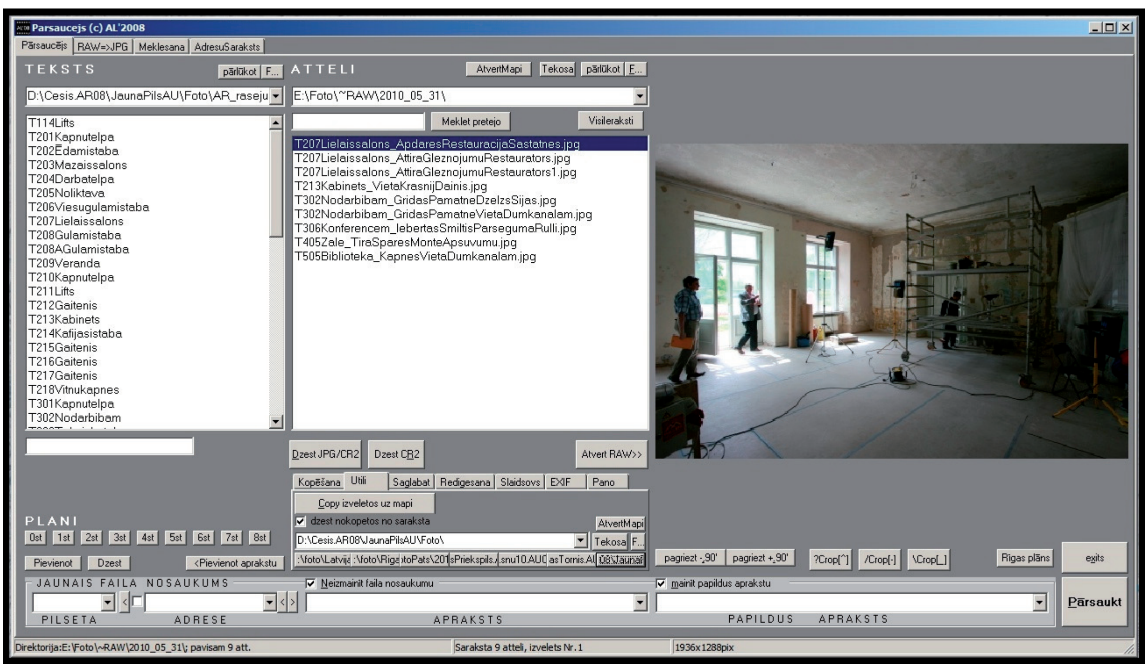

Figure 3: Screenshot of the program "The Renamer". See description within the text.

4. TAGGING OF THE IMAGES

The structure of image tagging has developed over time from computer-oriented systems to more user friendly descriptions. One of the older systems is Iconclass (Iconclass, 2010), which has been under development since 1950 for "a systematic overview of subjects, themes and motifs in Western art". The idea of structuring the the iconographic descriptions of the artistic features is implemented according to special codes, which could be easily processed, using computers. However, taking into account all the possible situations and the themes depicted by artists all over the history, the system, although very logical, has grown into a rather complicated structure and the computer - oriented code should be eventually replaced by a more modern natural language descriptions.

5. CONSERVATION - TAILORED TAGGING

Keeping in mind the success of the described approaches and the principles of the commercial applications, the task was to make a conservation-oriented application on its own, suiting the everyday needs for working with visual information. Nothing achieves perfection all at once, so the tool was designed to be upgradable and easily improved. It has been under continuous development for ca. 2 years, and the result has justified itself.

The application is designed as image file management program, called "The Renamer", written in Delphi (Delphi, 2010), and is intended and used for architectural conservation and particularly in reconstruction design process.

The typical work flow is as follows:
[a] acquiring the image (downloading photographs from the camera, scanning, finding on the internet),
[b] writing the GPS information, if available,
[c] converting the image to the single format (jpg) - getting the thumbnail out of the raw file, converting from other image formats (png, gif),
[d] tagging the location,
[e] tagging (indexing, keywording) the subject.
[f] copying of the selected files to the target location (e.g. a folder for object, travel, research theme etc.).

Tagging or keywording, which forms the most essential part of the program, saves the particular tag after successful renaming of the image file in a separate text file. So the once - applied tags can be conveniently used again for further images or as keywords in the image file retrieval process. All the supplementary files created by the program are simple text documents, so they can be reviewed and edited within any available text processing program. This type of approach also allows the possibility to work with both image and text files, even if the original application is not available, which eventually might be the case at sometime in the distant future.
The program also provides the "management" functionality, bridging the work with other programs, in particular, opening of the selected file in an image processing programs (GIMP), finding and opening the associated raw file (Rawtherapee) for high quality image processing, visualization of the GPS tags (Geosetter), creating and saving copies of images with lower resolution for web or e-mailing etc. (Web, 2010)

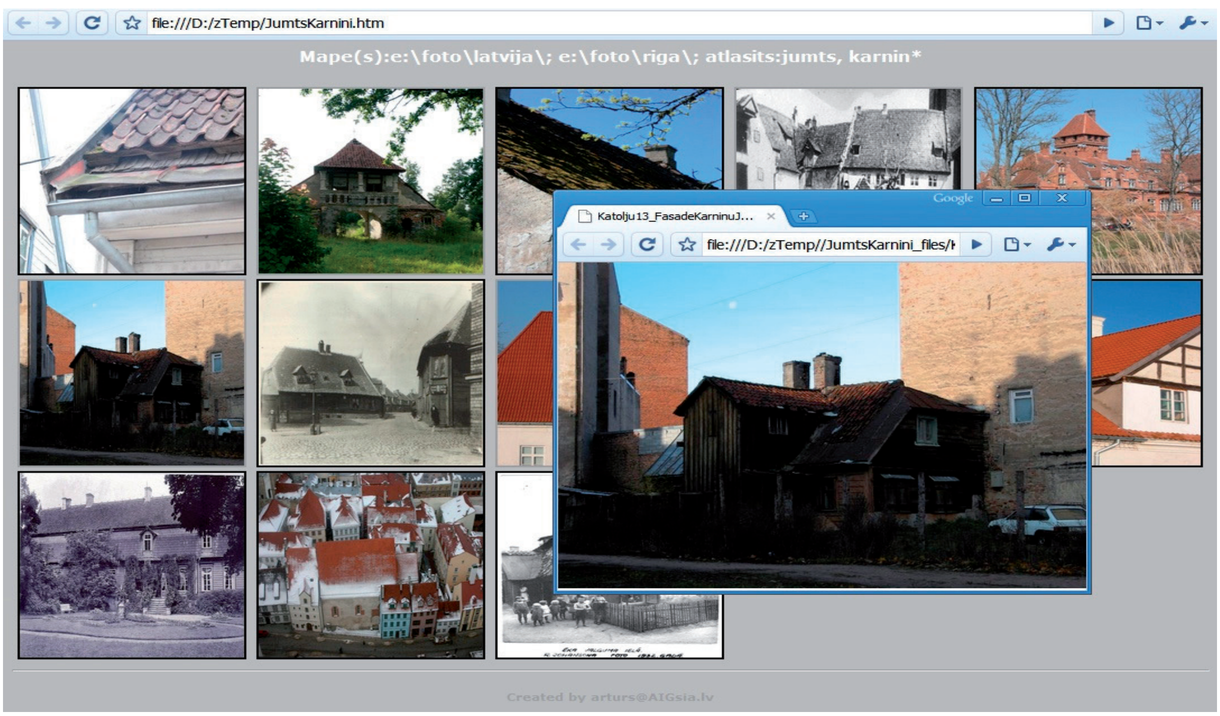

Figure 4: Result of the query on "Roof" and "Tiles" in Riga and Latvia, opened in the Google Chrome

The "Search" tab provides the function of finding the images across the computer according to the tags in their filenames. After retrieval, the selected images can be further indexed and analysed, if necessary. Again the result of the work is simple tagged image files, which theoretically can be reviewed, processed or organized any regular file management program.
Figure 3 shows the program at work, being opened at the tagging page. On the right side, below the preview of the selected image there are keyboard shortcuts for rotation and basic cropping. By clicking on the image it opens in a separate window for closer reviewing, using external image viewer (Irfanview, 2010). The centre part of the program contains a list of images in the current folder, and below it there are tools for copying, editing, stitching, etc. The left side of the page provides pre-created text information, like the description, created during the photo session or pre-created tags, which can be added to the image. In this case it is the room schedule of the particular building, which is used to mark the files. The buttons below provide quick access to the plans of the building, which are stored in the object folder, for quick reference. The function of tagging or keywording is provided within the lower line, where the new file name is formed. It consists of two location keywords (the City and the Address), and two descriptions of the subject. The filename is written without spaces in order to provide backward compatibility with command line applications. Each word or term within the name is separated from the other, being capitalised. Therefore a typical file name would be:
"CesisNewCastleT207Hall_CeilingRepairScaffoldingWindowsCoveredFloor.jpg".

6. MANUAL VS. AUTOMATIC TAGGING

Indexing of the images is very time and resource consuming. To ensure the necessary degree of accuracy and reliability, the tagging has to be done by a highly qualified specialist, preferably by the author of the images. The task of the application described above is to make the process of tagging as convenient as possible. Of course, human input may involve errors, such as faulty or inconsistent descriptions or incomplete captions. Nevertheless, they can be easily improved in the process of further reviewing and retrieval by the author himself or by any other reviewer of the image files. Also the process of tagging is considered as analytical and creative, allowing the operator to rethink the image and its contents. In this context application has to provide all the necessary background information, such as examples of similar objects or references to publications, historic maps or direct access to online resources

7. USING THE TAGGED IMAGE FILES

Once the images have been tagged, the data contained within them can be retrieved in numerous ways. Once again, the simplest way is to use the file manager, built into the system (like Windows Explorer), to find the files matching the given text strings. This method gives acceptable results, unless the number of images grows too large. Also currently, it is not possible to search using logical operators, or to limit the search to several specific folders where the photos might be located.
The described application "The Renamer" currently overcomes some these limitations. After doing the initial search and the list of matching images is created, the user can input the phrase, which will be searched within the list. The further work like sorting, filtering, image retrieval can be done according to the textual information, which substantially speeds up the processes. After filtering, the selected image(s) can be exported as a list for future use or saved as an htm file (See Figure 4), which can be easily made available online.

8. FURTHER DEVELOPMENT

Although the tagging of the images by means of file names has been realised, further work will include working with IPTC or XMP metadata. Nowadays most of the image processing programs allow reading and adding "hidden" keywords to the files, which widespreads the use of tags in everyday practice, even without any specific tagging or image retrieval application.
However, none of the present commercial systems, claiming that they can be used for image tagging, really suit the needs of the conservation architect. Most of them are oriented towards other specialities (photographers, publishers etc.) and / or are too general, to be conveniently used for specific purposes (e.g. Photo Mechanic, Adobe products: Bridge and Lightroom or iView MediaPro).
Eventual moving of the application from the local computer to a web server would allow multiple user input, as well as wider access across the world wide web.
The application is currently being used for the specific needs of the author, so the tagging is done in Latvian. Converting it to online application and widening the circle of users, will eventually involve the need to translate the tags into other languages, e.g. English. However, the basic principle - use of simple tags - allows the acquisition of the metadata in simple text format and the potential to translate it using currently available online translators, e.g. http://translate.google.com/ or by providing a simple vocabulary. Adding a special language module would be part of any further development.

9. CONCLUSIONS

The described method for image file tagging and the implemented application "The Renamer" is a simple, yet practical tool to assist in decision - making within the conservation design field. Assuming that the necessary standards are kept, the resulting files provide systematized and reliable data, documenting the built heritage. By further expanding the file organization methods, it can be converted to online image database, allowing access to multiple users and reviewers.
Treating image filenames as standard text information allows fast and effective method of image management, which can be further developed in the future.

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MURAPARA PALACE: AN EXPRESSION OF BRITISH FEUDAL LORDS, ITS CONSERVATION ISSUES AND PROSPECTS

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KEY WORDS: Murapara Palace, Zamindars, Architectural Heritage, Conservation

ABSTRACT:

The significance of conserving and preserving architectural heritage is now universally recognized. But Architectural conservation and restoration do not hold any priorities in a country like ours where the basic demand for food, shelter, education and health are yet to be met at a satisfactory level. However, it can be said that cultural identity is the touchstone of all nations. This conservation and restoration ensures the continuation of life and value of historic buildings. Conservation in developing countries seeks national and cultural identity. There are many notable historic buildings, which are mostly perished with the passage of time, or only survive precariously in highly changed circumstances. As for example, some buildings in Dhaka and a series of Zamindar palaces in outlying areas, erected during British period survive only in desolation and neglect. Their fate is very uncertain. Murapara Palace is one of the examples of such buildings. Unless the government promptly takes decision to save them, they are doomed to destruction. This paper will attempt to identify the practicing issues and possibilities from the conservation and restoration point of view, focusing on the Murapara Palace complex on the Dhaka-Narsingdi Road. The Palace is significant because it stands with its glorious historic memories of the British Zamindars and a unique blend of Colonial and Mughal style. The discussion will mainly give direction to provide a base-line data, information and documentation to identify historical and cultural assets. Thus bring the complex has been brought to limelight to make people aware of the conservation and restoration of this historic heritage, which is now going into obscurity.

1. INTRODUCTION

History of the past Bangladesh is being crowned by both human and natural resources. Either we can be passive observers in a process of inevitable change or we can influence the process itself by awareness and understanding of our heritage- the bedrock of our future. Heritage is our legacy from the past, what we live with today, and what we pass on to future generations. Our cultural heritage is irreplaceable source of life and inspiration. It is through the dynamic art of conservation that we can observe and develop a regard and knowledge of traditions and the guiding principles that constitute a tangible link with the past. Therefore conservation and restorations of buildings are practiced as old buildings themselves have existed as long as cities have existed. In absence of adequate historical sources and writings, architecture as a vehicle of cultural expression and experience, is a veritable cultural document. So we can say that architectural conservation postulates prolonging the life of a historic built form, arresting all the man made and natural elements that are causing decay. The intension are clearly stated by sir John Marshall, the pioneer of archaeological survey in India "The object is not to reproduce what has been defaced, or destroyed, but to save what is left from further injury and decay and to preserve it as an heirloom for posterity" (Imamuddin, 1993) and the rationality of this paper is influenced by this.

The study area, Murapara palace is a 107 year old building [Fig 1] and a reflection of the power, lifestyle, and rituals of the feudal lords of British government, once who had a strong impact in our society. During the British period, these feudal lords called Zamindars [Landholders, who lease large tracts of land from the Government at British period] were responsible for construction of large number of magnificent palaces through the Bengal, symbolizing our tradition and heritage and culture of that time. Only few of these are maintained and preserved. But most of these cannot be used properly because of lack of maintenance and public awareness. Being a palace of the late 19th century, Murapara palace still stands in a better situation as an example of an affluent community. It is a unique blend of European and Mughal architectural style and can be a means of communication for the tradition and heritage of that period. Like many other palaces scattered around the country, this may also be destroyed in near future for lack of preservation in right time. From the field survey, it seems to be urgent that this palace with its beautiful surrounding environment and adjacent temples [Fig 2] should be conserved soon before it lost its original outstanding features. This paper is thus an effort to give introduction of the palace itself to those who are not familiar to it and thus bring it into limelight.

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Figure 1: View of the Palace

Figure 2: View of the Temples

1.1 Methodology

As an example of Zamindar Palace during British period, the "Murapara palace" with its remarkable architectural character, historical and political background and conservation possibilities, has never come to public eyes like many other historic buildings of the country. The drawings, plans of the palace and the temples have not properly been worked out before. Therefore, primary data has been collected through field survey and secondary data from literature review. Other sources have been the reports and documents published on the issues of conservation. Interviews with the people involved in architectural conservation, was also a help to get information on what has been going on. Site visit was carried out to get the live experience, photographic information and architectural detail documents.

1.2 Scope of the study

This paper is an approach to the ways and means of conservation of the Murapara palace. The document carries its historical background, architectural descriptions, its present conditions and possible proposals for conservation works.

2. LITERATURE REVIEW

2.1 Conservation Practice in Bangladesh

The socio-economic output of conservation has been recognized in many of the developing countries. Positive social transformation has taken place in most instances. Restoration and conservation should be considered of elite, but essentially as a complex to revitalize, reuse and reinsert for the general development of the society. According to the "BURRA CHARTER", Australia, ICOMOS, the conservation means all the process of looking after a place to retain its cultural significance. It may include maintenance, preservation, restoration, reconstruction and adaptation according to circumstance and will be commonly a combination of more than one of these (Rahman and Mamun, 1993). Conservationists and conservators considered themselves mere custodian of heritage. As the conservation specialist, Ruskin had said "they are not ours to destroy, they belong partly to those who built them and partly to all mankind who follows us" (Morris, 1877).
The history and culture of this subcontinent is much enriched. All the ruling bodies play an important role and attribute in architectural establishments. Thus, these symbolize particular civilization, significant developments. With passage of time some of these historic architecture, acquire greater significance in world heritage, and need to be conserved. The state of art in Bangladesh if reviewed, it can be said that architectural conservation is yet to be a wider public and professional concern, and the contemporary philosophy and concept of architectural conservation is yet to gain currency. Fund constraint, while an important factor in Bangladesh, is not the only obstacle that inhibits progress and development. Lack of motivation, lack of expertise in relevant bodies, absence of clear policies and priorities, absence of effective mechanism to execute and implement decisions are no less daunting. Yet it does not have a proper policy regarding architectural conservation. Being alarmed by the progressive deterioration of two monuments, Government of Bangladesh has made an appeal to UNESCO for the preservation of the Paharpur and Bagerhat monuments in 1972, acknowledged in 1980. A master plan was prepared with the assistance of UNESCO and UNDP in 1982.Besides these there are opinions in favour of protection of other buildings and built spaces of the past. Ahsan Manjil of the Nawab bari, the old high court building, Curzon Hall, Ruplal House, Lalbag Fort, Panam Nagar, a large number of zaminder palaces all over the country side , like Mymensingh Rajbari, Joidevpur zamidarbari and many others. Somewhere the preservation work has done without any sympathy, understanding or consideration for the architecture or aesthetics of the old buildings. Somewhere the significance heritages of these buildings were destroyed and have been considerably modified by local conditions.
Beside these, the physical features of Bangladesh are not so congenial for the natural preservation and maintenance of any monuments, historical buildings or any structure made of earth and bricks. The heavy rainfall, flood, storms, cyclones, nor'easters, soil erosion etc are the natural calamities which act against the maintenance of the man made structure. Man himself also played and often plays negative role on damaging these historical, archaeological buildings, monuments, forts-significance or egocentric motives.
Awareness to the traditional architecture in Bangladesh was not noticeable until 1980.About the same time, few conservation projects took place through a personal initiative of the then President and some external grants also arranged for impetus for several studies and mention-worthy projects. From then, the Directorate of Archaeology and the Department of Architecture, Ministry of Works involved directly in conservation work. It is very much encouraging to note the government's decision of September 15, 1993 (Rahman and Mamun, 1993) which proclaimed that, all government buildings will be conserved with their traditional architectural character reflecting their instinctive value. This legislation based on British laws with a bias toward archaeological preservation, is increasingly become inadequate and incapable to meet the present need of architectural conservation. Yet the concept of architectural conservation and awareness to heritage are still not established properly. However, the consciousness about the value and justification, and conservation as a means for economic regeneration is gradually increasing through out the architects and environmental groups. Nevertheless very few of these conscious people have academic and technical training needed to be undertaken any physical work. The issue of conservation was included in the Bangladesh National Building Code (1993). The newly enacted Building Construction Rules (2007) have kept provisions to provide protection of heritage buildings and asked for special consideration in buildings in the vicinity of historic sites (Rahman, 2009). It should be borne in mind that architectural conservation is multi disciple and need involvement of many professionals. This process involves archaeologists, planners, architects, historians, engineers, sociologist, craftsman, and artisans etc. all of whom need

formal orientation to gain a common frame of reference. Building professionals alone cannot address the multidisciplinary of heritage conservation. These necessarily call for a mechanism allowing community participation in decision making and sharing on shouldering of responsibilities. Architectural conservation involves legislation, public education and money. Here laws are important tools, to shape architectural conservation practice and the role of voluntary organization and private sector are also very significant. Overall political will and the role of government is utmost important in this issue of conservation in a developing country like ours.

2.2 The Zamindars

The system of land holding in ancient India is known as 'Zamindari' system. The Persi word 'Zamindar' ('Zamin' means land and 'dar' denoting to have, hold or possess) means owner of land on the condition of revenue collection for the Government. (Akhtar, 1987, p30) Usually the peasant paid one third of the gross produce of land as share of tax to the Zamindars and Zamindars handed over the collected taxes to the authorities (keeping a portion for him). This system was the legacy of Mughal period. All categories of Zamindars under the Mughals were required to perform certain police, judicial and military duties. With elements of both fiscal and political power at their disposal, Zamindars exercised enormous local influence that made them the most undisputed potentates within the bounds of their territories. At the end of 17th century, Murshid Quli Khan started 'Jaigir' system for the state and 'Ijaradrs' or contractors for the collection of land revenue. However, he again discouraged this at the first of 18th century.

At the end of the 18th century, the British government made these Zamindars as landowners, thus creating a landed aristocracy in Bengal and Bihar. Before the acquisition of 'Dewani' [Revenue authority] system in 1765 established by the East India Company, these feudal aristocrats or Zamindars were invariably 'absentee landlords' owning vast tracts of lands which spread often over districts. Their life in pomp and style were completely influenced by western society. They used to live an exclusive life within high social orbit, encapsulated from the rest of the society. These feudal lords were responsible for construction of a large number of magnificent palaces throughout the Bengal. Their craze for imitating the western lifestyle reflected in their palace architecture, its ornamentation and decoration. Again, Mughal influences have also been noticed in their food habit, cloth, culture and in the architectural appearance of their palaces.

At that period, most of the Zamindars were from upper class Hindu families. They had strong belief in their religious rituals. As a result, space with much ornamentation to perform their rituals was the most impressive part of their palace complex. These reflect not only the skilful architectural practice of that period but also the social status and life style of the Zamindars. Therefore, Murapara Rajbari (The palace locally known as Murapara Rajbari) is one of the examples of such grand complex of those affluent communities.

Unpleasant tales of torture and indignities inflicted upon defaulting farmers were very common story about them. The twentieth century developments like Indian nationalism, politics of agitation, Muslim separate electorate and separatist politics had seriously undermined the social authority of the Zamindar class, which was politically moderate and loyal to British Government. Peasant politics was entirely against Zamindari system. As most Zamindars were Hindus, the Muslim peasantry, who formed the majority of the population in the countryside, was vehemently against Zamindars. At the end of 19^{th} century their power upon Prajas [Local people who pay tax (Khazna) to Zamindars] started descending and they were submissive by the British leaders. After partition (1947) Government acquire most of their land. Thus these feudal lords gradually loss power, property, fame, and thus create an important part in the history of ours. The Zamindari system was finally abolished in Bangladesh under the East Bengal State Acquisition and Tenancy Act of 1950 (Akhter, 1987).

3. MURAPARA PALACE

3.1 History of Murapara Palace

The founder of Murapara Royal (Zamidar) family was Ramratan Banarjee at the end of 18^{th} century, appointed by British Government as treasurer of Natore estate. He in 1296 B.S / 1889 A.D. built two beautiful temples. And a two-storey palace built by Zamindar Bijoy Chandra Banerjee, younger son of Ramratan Banarjee in 1304 B.S./1897A.D. Another source says it was Ramratan Banarjee, who constructed the palace in 1889 but the other source says he just established the basement of the structure. Protap Chandra Banerjee (A close friend to Poet Rabidranath Tagor's grandfather Prince Dwarkanath Tagore) left his old traditional house and made new palace behind the old one in 1889.

Zamindar Ram Ratan Banerjee acquired large properties by dint of his honesty, which was further extended by his grand sons-Ishana Chandra and Pratap Chandra. Later Zamidari [Area for revenue collection] was divided among Dinesh Chandra, Tarak Chandra and Keshab Chandra-all descendants of Ramratan's eldest son; and Jagadish Chandra and Ashutosh Chandra –The sons of Bijoy Chandra who was descended from Ramratan's younger son. The property was further fragmented and shared among five other descendents of Ramratan's brother,namely Birendra Chandra, Brajendra Chandra, Nripendra Chandra and Gyanendra Chandra Banerjee (Ahmed, 1986). In 1909, Jagadish Chandra Banerjee completed the structure and became a landlord. Jagadish Chandra Banerjee was very famous because he was twice elected at Delhi Council of State. Landlord Jagadish Chandra Banerjee established many things for the tenants in his territory but on the other hand was also very vulgar towards his tenant. Overall he was very powerful, brutal and vigorous landlord of the Murapara. In his ruling period, he torched and cut off his tenants' hair when they did not pay their tax (Ahmed, 1986).

At the last phase of colonial period in between 1920~1930, like other Hindu Zaminders, this Zaminder family also left this place and migrated to India. It is also heard from the local people that inter family conflict and clash for power force them to leave this place. Migration created a change in the ownership of the building. The palace was acquired by the government under the Abandoned Property Act, taking advantage of the absence of the actual owner. After the partition in 1947, the palace was used as prisoners' school under Pakistan government. The complex is now occupied by Murapara Degree College, which was established in1966.

3.2 Location

Murapara palace (Rajbari) located in Murapara village [Fig 3], about twenty-five kilometeres (16 miles) southeast of Dhaka (Capital of Bangladesh), on the western side of Dhaka-Narsingdi Road. A three-mile brick paved road on the west of the main Dhaka-Sylhet Trunk road connects it. The palace occupies the eastern bank of Sitalakhya River and opposite

Rupganj across the river. The road in front of the complex connects Murapara with Vulta Bazaar, passing between the temples and the riverbank. Future expansion of Dhaka on the eastern side (Development of Purbachal New Town) makes Murapara very close to Dhaka. Development of a Bridge and river transport makes the communication distance from Dhaka very easier and shorter.

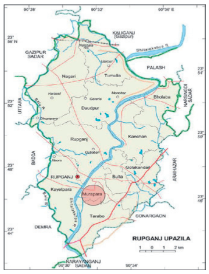

Figure 3: Location of Murapara

3.3 Architectural Features, Ornamentation and Decoration

The following section is the detail description of Murapara palace complex from the physical survey conducted by the authors.

3.3.1 The Palace: The two-storey palace [Fig 4] is almost 160' long, rectangular in plan and has a grand frontage [Fig 5(a)] facing west across the fenced off pond [Fig 5(b)]. There is an imposing central porch with semi-circular arched entrance, which is flanked by 4 pairs of Corinthian columns on both floors. These are surmounted by triangular pediment. Thus, the front facade formed a well-composed elevation by three projections consisting of the main entrance and two terminating wings at both end. This facade is attractively composed with red bricks and white plaster ornamented with floral pattern.

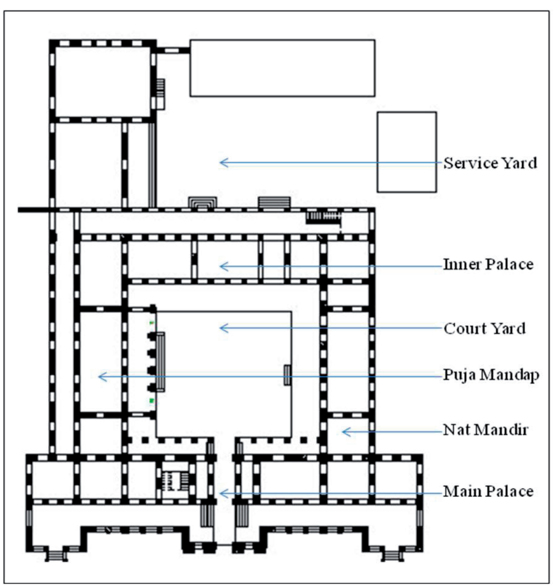

Figure 4: Plan of the Palace

An eight feet wide veranda [Fig 5(c)] runs in front of the palace at both levels, providing access to rooms. The depth of the veranda was used as shading device from the western sun. It has semi-circular arches [Fig 6(b)]. The area within the arches are decorated with cast iron framing [Fig 6(a)] and filled with green, red and blue tainted glass [Fig 6(b)]. The floor of the veranda demonstrates as a colourful mosaic pattern by casting shadow from the sun. It has a nice view of the whole complex up to temple and river.

5[a] 5[b] 5[c]

Figure 5: [a] Entry view of the Palace
[b] View of the Palace from Pond
[c] View of the Veranda and Wooden Beams

6[a] 6[b] 6[c]

Figure 6: [a] Iron Railing
[b] Semi-circular Arch with Tainted Glasses
[c] Entry of the Inner Court

The main entrance leads to the stair-hall, which gives entrance to the upper storey of purely private verandah. The veranda gives access to the five large hall rooms, which were used for public functions. The floors of these are laid in black and white marble and mosaics in various geometric patterns. Both roof and floor are rested on wooden beams [Fig 6(a)]. The parapet all around is relieved with a band of diamond shaped punches. In the frontal parapet there are six small pinnacles covered by Bengali-charchala (A Bengali style of roof design) dome.
Looking inside through the main entrance foyer by an Iron Gate [Fig 6(c)] of the palace, there is a large open paved around fifty-five feet square courtyard. This internal courtyard is also with internal verandah of upper storey by a cast iron spiral stair. It is surrounded by different structures like a two storey inner palace [Ander-Mahal: private compartment] in the east [Fig 7], a single storey temple [Nat Mandir] at the south [Fig 8] and a flat roofed single storey temple [Puja-Mandap] at the north [Fig 9].

Figure 7: Ander-Mahal

Figure 8: Nat Mandir

Figure 9: Puja-Mandap

The northern temple chamber has a large mandap [open hall], which was the place of interaction between the villagers and Zamindar family on the only occasion of Durgapuja [A famous religious ceremony of Hindu believers]. It has a frontal veranda, entered by an elegant flight of steps from the paved central courtyard. Its southern facade is composed of five semi-circular arched openings, supported by a bundle of eight slender Corinthian columns. The whole facade relieved with floral design in plaster, which reveals the taste of the feudal lord. The two storey building [Ander-Mahal] situated at the eastern side of the courtyard behind the front line buildings, accommodates six rooms at ground floor and five large halls on the upper floor level. There are also two small courtyards followed by the main courtyard. These two were used for service or other facilities like outhouses, servant quarters and stables.

3.3.2 The Temples: Within the western perimeter and on the eastern bank of the Sitalakhya River, there are two conspicuous temples [Fig 10 and 11]. Both are facing south, placing side by side and rested on a low plinth.

Figure 10: View of the Temples

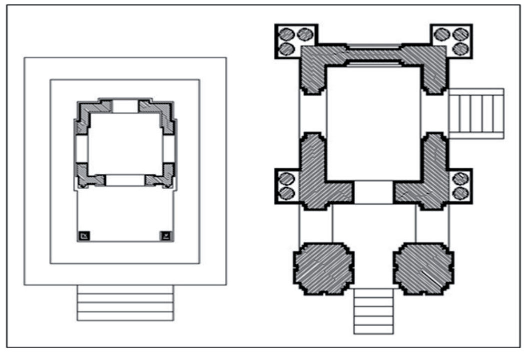

Figure 11: View of the Temples

The smaller temple [Fig 12] had a frontal porch on the south made of red sand stone. It is rare building material, imported from India. The less ornamentation proves that the local craftsmen were not accustomed to the material. No experiment could be made of making arched opening or curved surface, because of the large size of stone. A small marble stone plaque is placed in front of the porch bearing the date and name of builder in old Bengali script. According to this inscription, Ramratan Banarjee in 1296 B.S. (Ahmed, 1986) built it. On the stone facade behind the porch, the icons of different god and goddess of hindu believers like Sri-Gauranga, Ganesh, Yamuna, Lakshmi and Srikal carved in high relief.

Figure 12: Different Views of the Smaller Temple

Figure 13: Different Views of the Larger Temple

The adjacent larger temple [Fig 13] was more ornamented, also facing south, made of bricks. According to plan, it has a square shaped (10’x10’) shrine with a frontal veranda. The shrine surmounted by a ribbed dome supported by octagonal base. This large onion shaped dome is crowned by four kiosks [Fig: 13b] at each corner. The dome was designed with a combination of trefoil, sharply pointed and semi-circular arches rested directly on Corinthian pillars. Projected eves or cornice supported by ornamented console at the roof level is also an important feature of this temple. Its facade has attractive stucco-decoration of floral and foliate motifs. This frontal facade is terminated by Bengali Chowchala dome [Fig 14(a)]. There is no space left on the base of the temple.

14[a] 14[b] 14[c]

Figure 14: [a] Bengali Chowchala dome
[b] Kiosks
[c] Entry of Larger Temple

3.4 The Complex: A Blend of Different Culture

In the later part of the 19th century, some buildings in Dhaka and a series of Zamindar palaces in the outlying area erected during British period are influenced and enriched by different styles. Murapara Palace was one of the examples of such buildings. The plan of the palace was marked by symmetrical composition. Its large hall rooms, staircase in the centre of rectangular block and featuring classical columns, attractive triangular pediments, semi-circular arches, and foliated motifs in plaster are familiar features of late renaissance (English) period. The unique mix of red brick and white plaster on facade, wooden stair are typical of Colonial influence. At this time, some new architectural elements collected from Gothic style introduced in almost all buildings, like the semi-circular arches [Fig 15(a), (b)] (replacing 2 centred, 4 centred and multi-cusped pointed arches), triangular pediment carried on Corinthian column, foliated motifs. All these elements reflected in Murapara Palace. Its massive appearance and Bengali charchala dome in frontal parapet are typical of post Mughal architecture. Its traditional temple finial at the top of front parapet and ornamentation illustrates a blend of Mughal and European taste.

Figure 15(a): View of different types of Arches

Figure 15(b): View of the different types of Arches

In spite of all these, the zoning of the palace complex was mainly motivated by traditional design. The Andar-mahal or private zone, internal family courtyard for women, backyard with pond for service facilities, puja-mandaps and natmandirs are pure Bengali style. All of these functions generate from traditional demand.

From the history of Zamindars, we also find that most of them were Brahmins with strong religious beliefs. They built two types of spaces for worship and ritual purposes: one for feudal class of the society like Zamindars where they perform their daily rituals; a small temple only for Zamindar family and the other was a grand puja-mandap for celebrating the annual Durga-Puja (Famous religious occasion of Hindu religion) with the relatives, guests and villagers. This type of space also exists in the main building. It represents our own tradition.

Beside this, the two temples on the western side are a mixed of Colonial, Mughal and Bengali architectural style. Onion-shaped dome with shoulder of Mughal style, Corinthian pillar of Colonial period and charchala dome (Four sided dome) of Bengali origin make the temple universal. Above all their ornamentation, decoration and material choice reveals the intention of the builder to make their edifice superb. Thus the individuality of Bengal's architecture comes from such an ultimate resolution of a series of stylistic experiments in a blend of eastern and western architecture that produced an extraordinary heritage of palaces unparalleled anywhere outside Bangladesh. The Murapara Zamindarbari undoubtedly is one of the finest examples of feudal palace architecture developed in the 19th century.

3.5 Existing Condition

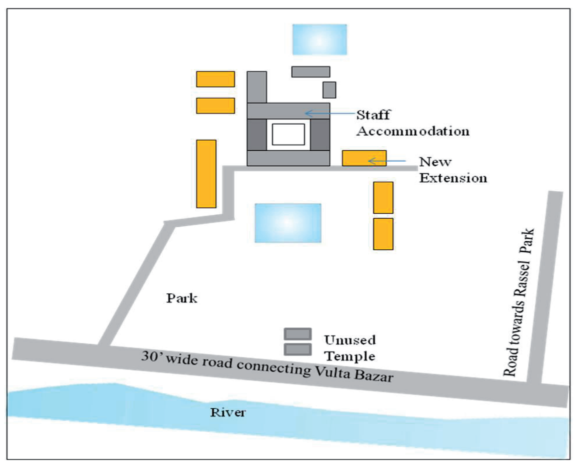

Figure 16: Schematic zoning of Existing condition

The palace complex [Fig 16] is now legally occupied by Murapara Degree College [Fig 17]. The ground floor of frontal palace is now used as administrative zone and teacher's room and some classes held at the upper storey. Only a few years ago the college can use the Puja-mandap at north and Nat-mandir at southern side as their classrooms. However, from a very recent survey, it has been found that these two buildings are in a very deplorable condition [Fig 18] to continue class.

Ground floor of the rear building is used for the accommodation units [Fig 18] of college staffs and its upper storey is not at a state of use. To meet the growing demand, new buildings added on the north and south for college activities. Those help to increase the destruction of original fabric of the complex. The wall plastering, the ceiling plaster in the Ander Mahal, the tainted glass, floral decoration of plaster, cast iron stair [Fig 21(a)], railings and parapet – all are in the process of damage.

Wild vegetation grows [Fig 19] and roots penetrate deep into the internal structures and in service yard [Fig 20]. Water penetrates through all the cracks and crevices, damp spread all over the palace. The surface peels off with all its artistic decoration.

Figure 17: Degree College

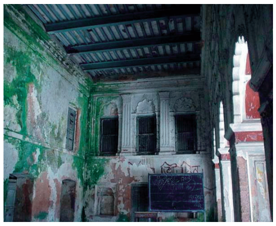

Figure 18: Damp in Wall

Figure 19: Growth of Vegetation

Figure 20: Service Yard

In Murapara Palace complex, most failures of old fabric are resulting from lack of maintenance or inadequate protection from the disastrous elements. Inappropriate repairing methods and materials used to protect damages, often contribute to the deterioration and loss their originality. Smooth stucco is most frequently used in need of repairing defects in plaster. It is extremely unwise to use modern, harder setting types in repairing work. It is therefore of prime importance that, the material used for plastering should match as nearly as possible to the nature of the old work. (Ashust, 1988)

21[a] 21[b] 21[c]

Figure 21: [a] Broken cast iron stair
[b] Ruinous view of larger temple
[c] Class room in the palace

The two Temples on west perimeter adjacent to the road left without any proper attention. As few numbers of people in the area belong to Hindu community now, for last few years these two remained unused and have turned into ruined condition. Both are now abandoned and decaying shrine for lack of maintenance. Its plaster, arches, plinth [Fig 21(b)], kiosk, parapet all are in process of complete deterioration. These need immediate steps to save the structure from further damages.

4. ISSUES OF ITS CONSERVATION

Buildings and monuments are the products of accumulated wisdom expressed through the language of space and form. These symbolize a particular civilization, a significant development, or a historic incident and become significant in our culture and national life. Architecture is a vivid expression of a society's social, economic, technological and cultural achievements at any point of time in history and in a particular geographic area. In absence of adequate historical sources and writings, architecture is the common denominator between generations of people, a common means of communication with the tradition and heritage of a nation. A civilized people must have the right to know about its origin and roots in the local, regional and in world context. Hence, it is the moral obligation of one generation to preserve this rich inheritance, held in trust for the future generations. Preservation of architectural work is, therefore of immense importance, for a society that values its past and cares for the posterity. (Rahman, 2009)

The early history of Bangladesh is at best legendary. In two thousand or more years of its history, many dynasties [Kings, sultans, Mughals (1610-1765), British (1765-1947)] have ruled and disappeared and left their mark. Those are the material evidence of our past, symbolizing the society and culture of certain periods and have been still visible in many place throughout the country. Like many other developing countries, lack of awareness to the accumulated value of traditional architecture in Bangladesh has put these structures in obscurity, disuse and abuse leading to faster decay. Here nature also plays an initiative role for the process of destruction because of its climatic behaviour. Therefore, a miniscule fraction of the number it had in its original glorious days are surviving in dilapidated condition. People of that very locality are often oblivious of their treasure and could not care less.

Murapara palace is one of those rare Zamindar palaces that remain in a better condition beside the riverbank of the country. Whereas devouring of settlements by the rivers with ever-changing courses is a common threat to the longevity of cultural property of Bangladesh. Therefore, the palace with its architectural, aesthetic, historic, and iconic value, have been added a great emotional significance as the emblem of our cultural identity and hence are a part of the heritage. After observing the surrounding situation one can easily perceive it as a cool and calm place, which has a feeling of ancient heritage; the openness of the park, the riverside and the pond has made the place very inviting. Therefore, the site provides a unique opportunity in restoring its unique character and should have proper decisions in right time. If properly conserved and promoted, it has every sign of becoming a renowned heritage site.

5. LIMITATIONS OF CONSERVATION

Bangladesh is yet to define her cultural policy, let alone a policy of architectural conservation. At present, there is little scope of it in Bangladesh. Here there are no responsible bodies or mechanism to deliberate and decide upon such issues. Most of our listed heritage properties are under the custodian of Directorate of Archaeology Department. They have allocated only US $ 280,000 annually to protect 372 monuments and sites scattered all over Bangladesh (Rahman, 2009). Hence, the conditions of most of listed properties are in ruined condition, the expectation from the palaces like Murapara (which is not under the list of government heritage) is in little hope.

Again, the lack of trained personal for scientific conservation at the technical level imperils our heritage properties. Financial involvements of the responsible authorities are not so overwhelming in case of our country. So as a whole we can briefly write down the limitations of the conservation works of Murapara Palace as follows:

- Lack of policies and priorities for the properties, which are not listed as a heritage of the country.
- Lack of public awareness, involvement and coordination between different relevant bodies.
- Absence of necessary expertise for the scientific conservation of the palace
- Resource constraints.

6. PROPOSED POSSIBILITIES

Murapara palace on Dhaka Narshingdi Road is an expression of British and Mughal distinct architectural features, as well as an example of our past cultural property. Being surrounded by a very beautiful environment: a pond in front, a ghat from a walking distance on west, scenic view from the river [Fig 22] create many possibilities and prospects for the conservation issues of this palace and temples.


Figure 22: Views surrounding the Complex

It is understood that any conservation plan must start with a road map for development; the master plan should have short, medium and long-term targets. Detail documentation of all the historic artefacts and spaces (Including topographic conditions, drainage and vegetation) in their existing state is the first step towards any conservation strategy. Without detail documentation (Scaled plan, elevation, sections, construction features and ornamentation besides close-up photographs, research to identify specific styles, etc.) any ancient building must not be touched. However, time and again we witness different initiatives of conservation and management of historic buildings without adequate documentation. The total conservation and management strategy for long term can be envisioned as follows:

Strategy 01: Adaptive Reuse:

The growing population makes increasing demands on the world's finite resources; we cannot afford to ignore the value added to the environment by our predecessors over centuries in creating homes, communities and reverted places. Only by rational use of existing stock, we can ensure the limited land and resources are not depleted unjustifiably. Investment in conservation is based on its economic viability. However, we cannot meet the expense of the resources to conserve these large numbers of buildings and sites and pay for there proper maintenance unless we find adaptive re-use functionally and economically. The best way of conserving buildings is to keep them in use. According to the guiding of ICOMOS [International Council on Monuments and Sites], the adoptive re-use of old buildings are often the best way to save the historic and aesthetic values of a heritage sites economically.

From the last forty years, the palace is occupied by the Murapara Degree College. Like many other abandoned palaces beside the riverbank of the country, it was not destroyed. This is the functional use of the palace, which not only helps to prevent this historical site from decay and completely out of use but also preserve in a comparatively better situation than others. However, the growing demand of the college requires the extension and thus many structures are adding day by day to the original fabric of the palace. According to the need they pay attention for the maintenance of the building with their limited resources. To congregate the emergency damage they frequently do the repair work. Nevertheless, proper precautions are not implemented for the preservations of its architectural significances. Thus, the college authority is converting the palace according to their need and requirement, which helps to loss its original character.

Therefore, the reflection of old heritages is not concerned with proper attention. Therefore, that proper planning and policy can be imposed on the use of the building. For the proper use and preservation of the palace complex, following four measures can be undertaken:

01. Proper master planning should be proposed to regain the original fabric of the complex. According to the riverine character of the country, rivers were the main means of communication and most of the palaces were built by the riverside and entered from the river through a grand ghat (cot). Temples on the riverside is another character of that socio-cultural context of that period. Further development of roads and embankment make the complex a distant from the river. Therefore, proper planning should be done to recoup the past ambient of the palace. The two temples, which stand in a very deplorable condition, must pay attention to protect it from further destruction. A connection between the temples and river can be developed to restore the original fabric of the site.
02. To meet the growing demand, new construction work can be done but by showing proper respect to the old building. Therefore ongoing unplanned construction (as the extension of college) work must be stopped immediately. As the most deteriorate condition is prevailing in the backside of the palace (inner-mahal), proper concern should given to this. All the functions have to be shifted from the main building. New constructions should be made having a distance from the main palace in a planned way surrounding the ponds of backside. So that they cannot interrupt the palace from the riverside.
03. The main building can have those functions, which are frequently used by the people but have less possibility of damage like library and all the classrooms should be located in the new buildings. The palace can be turned into a museum for its better maintenance or can be a heritage centre, which displays some cultural and historical information of that period. To some extent, this can help to preserve the beauty and demand of the site and develop as an important feature for the local people of that area. Furthermore it will be a fund generating source for maintenance.
04. To attract the tourist, Sitalaksha River can be a good means of communication. It is a very attractive place, full of panoramic beauties and in a very near location to the capital of Dhaka. The distance from Dhaka to Rupgonj takes only

one-hour journey. Therefore, the open space surrounding the palace can incorporate activities such as an amphitheatre, playground with proper landscaping including the river front development, the complex have an auspicious opportunity to grow as famous heritage site. In this way, we can develop it as conservation model for Bangladesh.

Strategy 02: Intervention Strategy

Under this strategy, the first thing that has to be done is the assessment of damage including detailed inspection of the building fabric. For this a multidisciplinary team has to be built including heritage and conservation expertise. It has to be determined whether temporary works, such as strutting and shoring walls or temporary roofing, are needed to protectcultural properties or specific components (e.g. carvings, murals). Damp proofing of all buildings in the palace, both from the ground level and from top and sides (Proper draining, injecting DPC below plinth level and providing coping or grouting on top of broken or unprotected walls, etc.) should be considered a priority and the task undertaken without delay. Repairing, retrofitting, consolidation and strengthening the structure of heritage buildings may be necessary elements for reconstruction program. Use of authentic materials and skills in repairing and retrofitting heritage buildings is a prime issue for conservation. Therefore, appropriate mortar and chemical test has to be done to identify the original composition of construction material for repairing work. Ideally, repairs should have no collision on the heritage value, authenticity, or integrity of a building and its surroundings. However, in cases where this is not possible, new material can be used for restoration work but obviously the impact should be minimal and reversible and the work should reflect recommended international practices. So that new material can be replaced at any time if getting information of the ancient one. Using local skills and materials may be the best way to achieve these aims. If traditional masons and crafts people are trained up and given a significant role in restoration activities, conserving cultural heritage can also help restore local livelihoods and further maintenance at any time.

Strategy 03: Management Plan

As long-term strategy, socio-economical sustainable planning for the complex conservation management and maintenance should be prepared for an apex monitoring committee composed of relevant experts may vet implementation.Whole process. In our country, we do not have technical expertise of ancient brick building. Therefore, we need to bring professional skills for technical conservation of this building from developed countries and conducting training program of local masons and artisan for further maintenance.

As fund constrain is the main problem for Murapara college to preserve this historic building, government can arrange appropriate sponsorship to restore the building with its original feature and allocate some yearly fund for the maintenance of this heritage. In this case developing a museum or heritage centre can also be an indirect fund generating resources for the building maintenance. To catch the attention of tourist, a suitable booklet providing information of this palace, its glorious history can be prepared.

7. CONCLUSION

The scholars may research, activity may act, but little can be achieved without the political will. To put in simply, motivation is the single most important force that can lead to tangible results. As conservation is still a relatively new concept in Bangladesh, people have less attention to conservation and restorations of this place.To pave the way for the journey on the path of architectural conservation, this paper might be an added one. This may help those, who are seeking information on the development and the conservation of outlying historical buildings of Dhaka. This paper is just an introductory work of this chosen palace for the several disciplines undertaking architectural conservation into a success story in the country.

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Remote Sensing for Archaeology and Cultural Heritage Management & Monitoring

MACRO-SCALE ARCHAEOLOGICAL PERSPECTIVES: REMOTE SENSING TECHNIQUES FOR INVESTIGATING ARCHAEOLOGICAL SITES IN CYPRUS

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KEY WORDS: Remote sensing techniques, Vegetation indices, Crop Marks recognition, high resolution satellite images

ABSTRACT:

Remote sensing has been widely used in the context of archaeological research. This study aims towards the use of high resolution satellite images for the investigation of archaeological areas through post-processing techniques. For this purpose time-series multispectral satellite imagery over Cyprus was used.
In the first part of the paper an introduction of the application of remote sensing in archaeological research is described. Afterwards case studies investigated in this paper are presented. The methodology followed by the authors is also indicated in detail aiming towards the detection and identification of archaeological monuments and sites. Different post-processing techniques have been applied in order to identify possible buried monuments. Time series remote sensing images have been found extremely useful in the context of archaeological research, although there are limitations in the analysis of them which can be only encountered through the use of multiple image processing techniques.

1. INTRODUCTION

Remote Sensing offers new perspectives in the archaeological research. Aerial photography (either oblique or vertical) may indicate crop marks, which in turn, can be connected to underground monuments (Bewley et al., 1999). The use of radiation in the electromagnetic spectrum, beyond the visible, such as thermal or infrared has been widely used for identification of archaeological remains under vegetation or even and deserts (Parcak 2009).
Remote Sensing as a non destructive method may be used as part of the investigation of an archaeological or historical site. In a micro-scale geophysical survey can provide valuable information for underground monuments while in a macro-scale air-photography and satellite images can locate traces of previously anthropogenic hazards (Sarris 2008). At the same time a combination of remote sensing techniques and Geographical Information Systems (GIS) can be used for monitoring anthropogenic and natural hazards, not only an archaeological site but also and its surrounding (e.g. Hadjimitsis et al. 2009).
In Cyprus, monitoring cultural heritage sites and visible monuments, is made mostly with on-site observations. However, this procedure which includes data collection, periodically observations for all archaeological sites or areas, and multi-analysis risk assessments is practically difficult with the existing practices and methods since this is time consuming and cost insufficient.

2. PREVIOUS PROJECTS

Remote sensing techniques have been applied, in different scientific field –including archaeology- systematically after the end of the 2nd World War. Parcak (2009) and Lock (2003) in their research report the benefits of the grayscale CORONA images for investigating a vast archaeological area. Fowler and Curtis (1995) have used the grayscale KVR satellite images for investigating the Stonehenge archaeological site.
However it was the Landsat satellite program which had made the use of satellite images for archaeology a reality. Although that the program had to overcome many difficulties (Parcak 2009), the low cost of the images was an advantage. Barlindhaug et al. (2007) have used Landsat images for the change detection around of archaeological site in Norway.
The use of new technologies, which can provide a vast amount of information in short time, is characterized as the only way for the archaeological survey of Cyprus (Iacovou 2001). In Cyprus the use of satellite and ground remote sensing techniques is very poor, although remote sensing techniques have been used widely in other areas of the world (e.g. Vaughn and Crawford (2009) investigating Maya civilization using medium Landsat resolution images; Alexakis et al. (2009) using multispectral and hyperspectral images (Hyperion, Aster and Landsat satellite images) for exploring the Neolithic sites of Thessaly in central Greece; McCauley et al. 1982 using radar images for identification of the so call "radar rivers" in Egypt's western desert). Satellite images have been used mainly for monitoring the anthropogenic and natural hazards of the surrounding area of known archaeological sites (c.f. Hadjimitsis et al., 2009) and not for identification of underground monuments. However, ground techniques such as geophysical surveys have been used

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in the Palaepaphos (Old Paphos) area. (c.f. Iacovou 2008; Iacovou et al. 2009; Sarris et al. 2008).
In contrast, this study aims to use high resolution satellite images in order to investigate archaeological areas through crop marks.

3. CASE STUDIES

For the aims of the study the south main archaeological sites of Cyprus located in the southern coastal part of the island were examined (from west to east): Nea Paphos, Palaepaphos (Old Paphos), Kourion and Amathus (Figure 1)

Figure 1: Area of interest

4. METHODOLOGY

In order to examine the use of multispectral satellite and aerial images over Cyprus, time-series images were investigated. Remote sensing pre-processing (geometric correction) and post-processing techniques were carried out in ERDAS Imagine 9.3 software.
Post-processing techniques included histogram enhancement, the computation of vegetation indices and band ratios, principal component analysis and photo-interpretation of the results.

5. RESOURCES

The satellite images applied in this study were captured within the period of 1962-recent (Table 1) and their footprints are shown in Figure 2.

no	Satellite image	Date	Spatial resolution
1	CORONA	1962/07/21	1-2 m
2	CORONA	1963/06/27	1-2 m
3	CORONA	1973/07/22	7-10 m
4	IKONOS	2000/03/14	0.8m
5	QuickBird	2004/07/19	0.6-2.4 m
6	QuickBird	2003/01/23	0.6m
7	Google Earth	Recent	< 30m

Table 1. Characteristics of the satellite / aerial images used in the particular study.

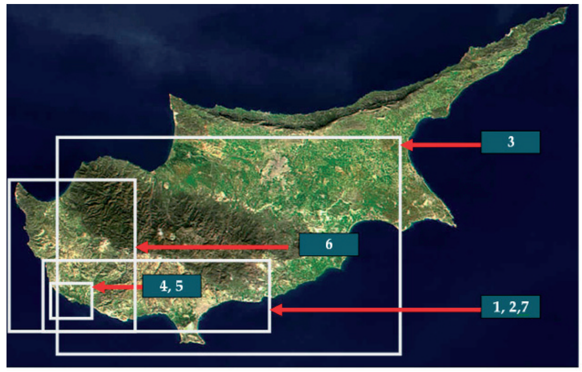

Figure 2: Footprints of the satellite images used in the study. The numbers indicated at the right of the images are taken from Table 1.

CORONA satellite images dated in 1962/07/21, 1963/06/27 and 1973/07/22 were used. It must be emphasized that these images have been declassified recently in 2002. CORONA satellite imagery have become a valuable tool to archaeologists due to its high spatial resolution and its low cost (Parcak 2009).
Furthemore, two high resolution QuickBird and one true colour IKONOS images dated in 2004/07/19, 2003/01/23 and 2000/03/14 respectively over the SW part of Cyprus were used.
Satellite images such as Quickbird and IKONOS can provide high spatial resolution data over archaeological sites. The spatial resolution of these images can be less than 1m and therefore can provide valuable information to archaeological research. However, the high cost is a major prohibitive factor for using them (Parcak 2009).
For the previously mentioned satellite images geometric correction was carried out using a high resolution map of Cyprus (1:5000). An affine transformation was applied, since the sites are located in flat regions and therefore the distortion of the photographs due to elevation is not crucial. Post processing techniques such as Normalized Difference Vegetation Indices (NDVI), Principal Component Analysis (PCA) and interpretation were followed.

6. IMPLEMENTATION

6.1 Interpretation and Enhancement

Interpretation of the CORONA images can provide valuable information since the landscape has changed a lot since their capture. Combining CORONA and free Google Earth images can show the current differences of the landscape. The use of Geographical Information System (GIS) tools, such as hillshade techniques (using the DEM of the area produced by ASTER satellite images) can benefit the interpretation of the images (Figure 3). Still, the resolution of the CORONA image (no 3 of the Table 1, Figure 4) was 10m and thus the results of processing were not encouraging, even after applying histogram techniques (Figure 5). Still information regarding the urban expansion of the south cities of Cyprus during the last 40 years can be extracted (Figure 6). CORONA highest resolution images, such as no 1 and 2 of table 1, were found more helpful. As it is shown for example in the case of Kourion interpretation of the images is easier (Figure 7) and can pinpoint the vanished landscapes before the official excavation of the Department of Antiquities started a couple of years after the particular image was taken (Figure 8).

This may be explained due to the noise occurred at the specific image. However this CORONA can be used for extraction of information regarding the urban expansion of the south cities if Cyprus, during the last 40 years can be extracted (Figure 6). CORONA highest resolution images, such as no 1 and 2 of table 1, where found more helpful. As shown for example at the Kourion archaeological site the visual interpretation process is easier (Figure 7). Such kind of grayscale images can show the landscape of the site, before the official excavation of the Department of Antiquities had begun, only a couple of years later that this image was taken (Figure 7 and 8).

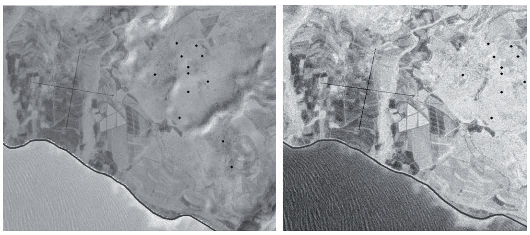

Figure 3: The used of hillshade effect (above). Image at the bottom shows the same area of Palaepaphos without hillshade effect.

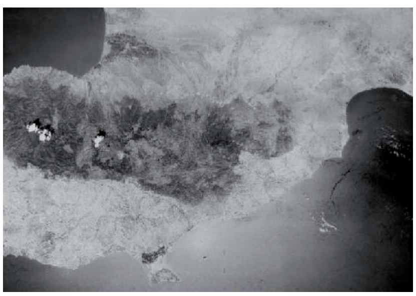

Figure 4: CORONA 1973/07/22 satellite image (10 m spatial resolution)

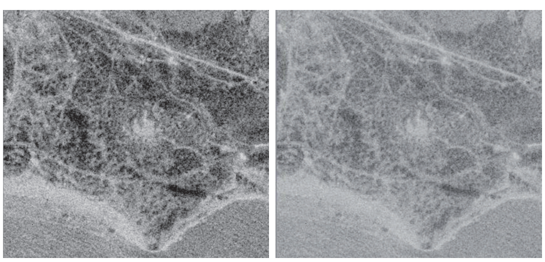

Figure 5: Kourion archaeological site (CORONA 1973/07/22) with different histogram enchantments

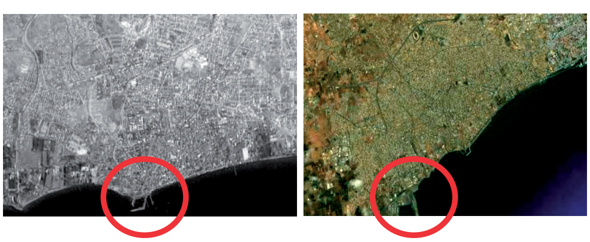

Figure 6: Urban expansion of Limassol city. The upper figure shows the urban area in 1962 while the lower figure shows the urban area in 2010 from Google Earth. Limassol harbour is circled for better comparison.

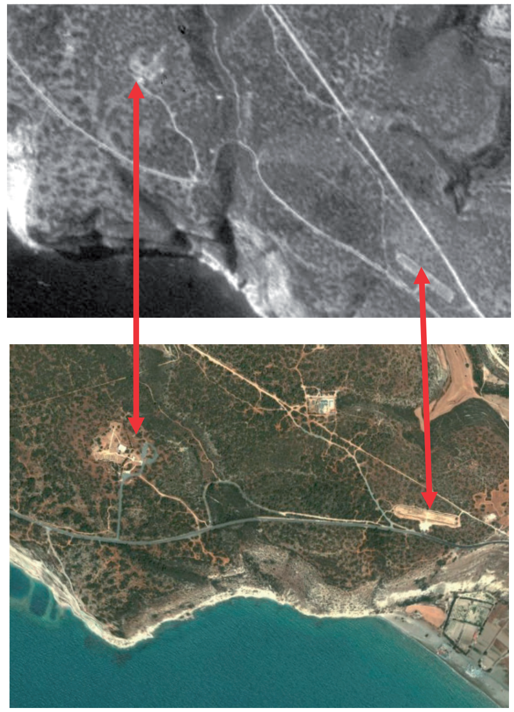

Figure 7: Kourion archaeological site as shown in high resolution CORONA image (up). The image below shows the current landscape from Google Earth.

Figure 8: Kourion archaeological site before the official excavations of Department of Antiquities (left) and after the excavations (right)

Except the grayscale panchromatic CORONA images, IKONOS true color and QuickBird NIR-R-B images (4–7 of table 1) were used in the photo-interpretation process (Figure 9).

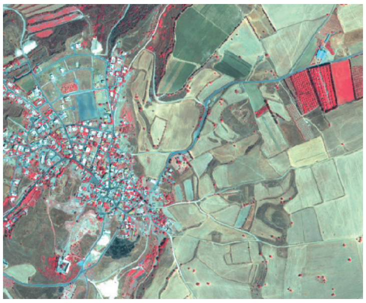

Figure 9: Nea Paphos (up) and Palaepaphos (bottom) archaeological site as shown in QuickBird images (2004/07/19 NIR-R-G)

In the case of Palaepaphos, at *Hadjiabdoullah* locality, an interesting crop mark was found. As it is shown in figure 12, this linear feature can be correlated to an underground wall (?) which projects to the west in the same direction as the excavated wall found a few meters away to the east. This feature is even more apparent when spatial filters and histogram enhancements are applied, as it is shown in Figure 10. However it is not recognizable in the visible spectrum as shown from satellite images of Google Earth (Figure 11).
This line is not recognizable in the visible spectrum as shown from satellite images such as Google Earth (Figure 11). During recently excavations taken place in this area, it has shown that this mark has not an archaeological significant but rather it was formed from geological rocks of the region.

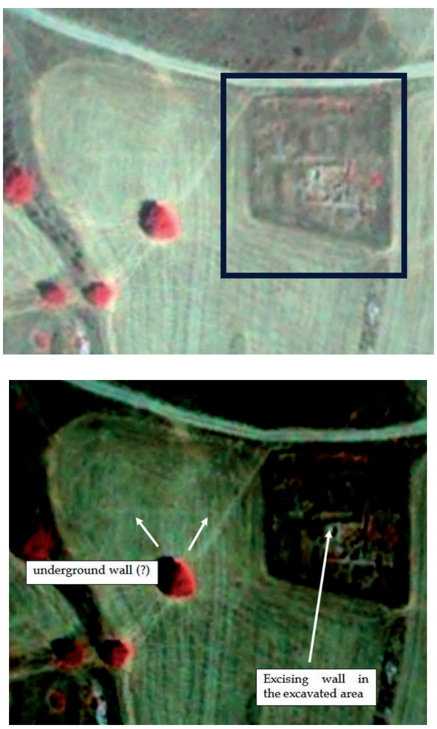

Figure 10: Underground wall (?) at Hadjiabdoullah locality as shown before (up) and after (down) the use of spatial filters and histogram enhancements

Figure 11: Hadjiabdoullah locality at Palaepaphos archaeological site as shown in Google Earth. Excavated area is indicated in a blue square.

An interesting round crop mark was also noticed in the archaeological site of Nea Paphos (Figure 12). This crop mark can be found in 3 satellite images.

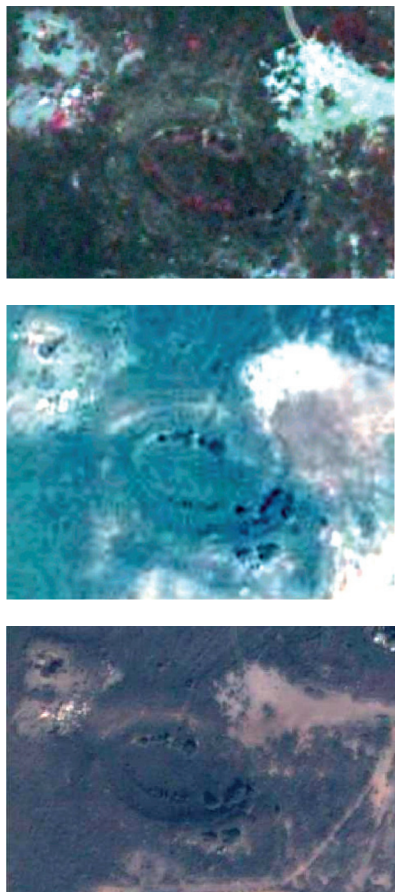

Figure 12: Circular crop marks at the Nea Paphos (from top to bottom: images 4-6 of Table 1)

6.2 Vegetation Indices, Ratio and Principal Component Techniques

Vegetation indices (VIs) have been widely used for the identification of burial monuments (Lasaponara and Masini 2007; Cavalli et al. 2007). High resolution QuickBird images and vegetation indices (especially NDVI) have been used in addition to simple ratio techniques and Principal Component

Analysis (PCA) for mapping crop marks which are visible in infrared spectrum. For the aims of testing the particular image processing analysis methods, two archaeological sites were selected: Palaepaphos and New Paphos.

Marchello locality at Palaepaphos archaeological site (Figure 13) has been excavated since 2006 with well published results (c.f. Iacovou 2008). Therefore *Marchello* can be seen as a "test-field" site. Using QuickBird satellite images taken in 2003, before the recent excavations, can provide to us useful information about the accuracy of these techniques in detecting subsurface relics.

As it was found high resolution multispectral images could identify an underground wall (shown with an arrow in Figs 13-15). While initial photo-interpretation of the satellite image (Figure 13) was not showing any indications of crop marks, after applying vegetation indices such as NDVI and SAVI (Figure 14) and simple ratios (Figure 15 up), a linear crop mark was recognized. However, in PCA analysis (Figure 15) the particular feature was not recognizable. Excavations of 2006 identified the linear crop mark with an underground wall with a width of about 1m.

Figure 13: *Marchello* locality at Palepaphos (VNIR-R-G QuickBird image –up- and Google Earth image down)

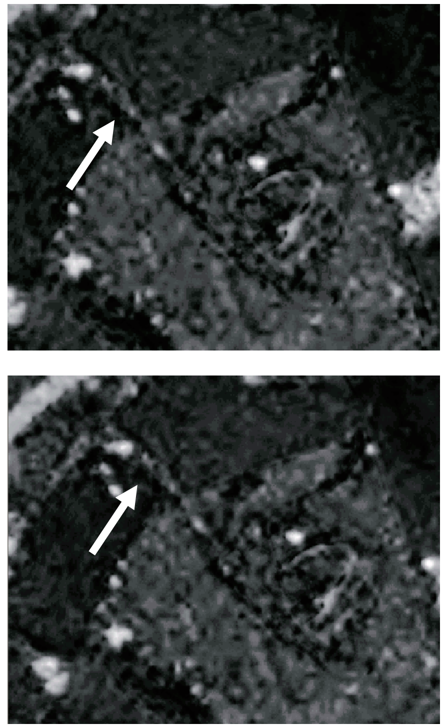

Figure 14: NDVI image (up) and SAVI image (down)

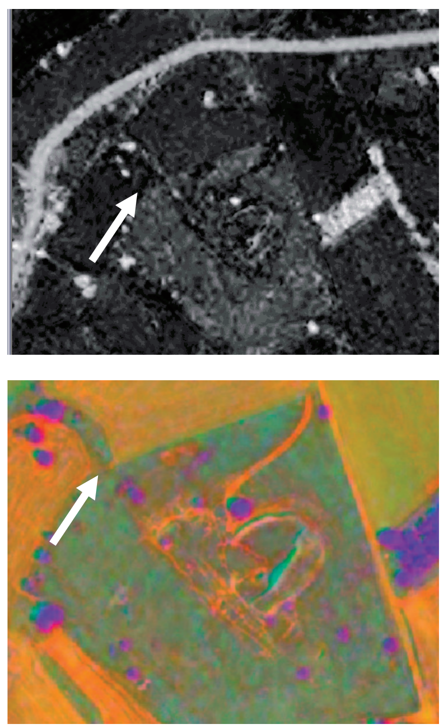

Figure 15: Simple ration (NIR/R) image (up) and PCA image (down)

7. CONCLUSIONS

The use of satellite images for archaeological purposes has indicated both benefits and limitations. A variety of post processing techniques have been applied in different satellites images over. CORONA satellite images seem to provide valuable information of vanished archaeological landscapes but noise observed in such images may distort the results. High resolution multispectral images are nowadays often used for archaeological purposes.
Still, different algorithms, such as vegetation indices, Principal Componet Analysis need to be applied in archaeological sites in order to extract useful information, while time-series satellite images can be used for validation of the results and examination of the evolution of the landscape.
The use of remote sensing for archaeology is very promising: the release of new high resolution satellites images (e.g. GeoEYE with spatial resolution 0,30 m) and the use of hyperspectral satellites are expecting to give new perspectives in the context of cultural heritage. However ground verification with archaeological excavations are necessary in order to confirm or not any hypothesis obtain from satellite images.

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APPLICATION OF NON-DESTRUCTIVE TECHNIQUES IN ASSESSING THE QUALITY OF STONE BUILDING MATERIALS IN CULTURAL HERITAGE STRUCTURES IN CYPRUS: USE OF ULTRASONIC AND 3D LASER SCANNING INTEGRATED APPROACH FOR DIAGNOSTIC TESTS

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KEY WORDS: non destructive techniques, ultra sonic measurements, cultural heritage monitoring

ABSTRACT:

This paper briefly describes the methodology and some preliminary results of an experiment that aimed to test non-destructive methods based on the integrated application of a 3-D terrestrial laser scanning and ultrasonic acoustic techniques in evaluating and assessing cultural heritage structures. The proposed methodology has been applied in the Medieval Castle located in the centre of Limassol in Cyprus. Future aim is to evaluate the state of conservation of the building materials of different monumental structures by investigating possible direct relationship between the ultrasonic measurement results with the reflectivity of the reflected 3-D laser scanner beam pulse transmitted to the surface target to be investigated. The authors used both ultrasonic and laser scanning methods for initial structural diagnostic investigation.

1. INTRODUCTION

Ultrasonic methods have been found to be very effective in detecting the elastic characteristics of stone materials and thus their mechanical behaviour even though data interpretation is very complex as elastic wave velocity depends on several factors such as moisture, heterogeneity, porosity and other physical properties (Casula et al. 2008).

Various researchers have implemented non-destructive techniques (NDT) and emphasized their importance in the evaluation process of masonry monuments (Di Tommaso 1993; Riva 1994; Riva 1997; Livingston 2001; Kourkoulis et. al. 2006; Masini et. al. 2008). Non destructive techniques for ancient or old buildings may serve several purposes that could be divided into three main categories.

The first one consists in the use of the NDT for diagnostic purposes of the state of preservation of a monument, which generally refers to: a) detection of possible voids, cracks and different types of flows within the structure, b) detection and evaluation of moisture content and capillary rise humidity, c) detection of surface deterioration and d) determination and evaluation of the extent of mechanical damage in cracked structures.

The second one concerns the more profound knowledge and understanding of a building in terms of its architectural aspect. Using NDT, it is possible to: a) detect hidden structural elements like pillars, arches etc. and b) determine the masonry materials used in the outer surface and for the nucleus of a structure, by mapping the heterogeneity of the different materials used (e.g. different kinds of stones, bricks etc.).

The last category regards the used of the presented technologies for monitoring and controlling restored portions of a monument. To achieve the above targets, a combination of different NDT is required for better results.

The pulse velocity method is a truly non-destructive method, which uses mechanical waves that cause no damage to the elements being tested. This method has been used successfully to evaluate the quality of concrete for more than 60 years. It can be used for detecting internal cracking and other defects as well as changes in concrete such as deterioration due to aggressive chemical environment and freezing and thawing.

The development of the pulse velocity method began in Canada and England at about the same time. In Canada, Leslie and Cheesman (1979) developed an instrument called the soniscope. While in England, Jones (1978) developed an instrument called the ultrasonic tested.

The basic idea on which the pulse velocity method is established is that the velocity of a pulse of compressional waves through a medium depends on the elastic properties and density of the medium. The transmitting transducer of the pulse velocity instrument transmits a wave into the specimen and the receiving transducer, at a distance L, receives the pulse through the material of the specimen at another point. The pulse velocity instrument display indicates the transit time, Δt, it takes for the compressional wave pulse to travel through the specimen. The compressional wave pulse velocity V, can then be calculated as the ratio of the distance divided by the transit time.

The time of travel is affected by the properties of the material of the specimen, as well as the presence of voids or cracks. Since the compressional waves travel through solids, the presence of cracks and/or voids has as an effect the increase of the transit time for the same transducer distance.

Figure 1 shows the three pulse velocity measurement configurations: the direct, the semi-direct and indirect. The best

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results are obtained by the first configuration, while the last one gives the least satisfactory results. Nevertheless, the indirect method can be used if it is required to detect possible changes in the properties of the specimen especially in monuments where it is in most cases impossible to use the direct method of measurement, due to the thickness of the elements.

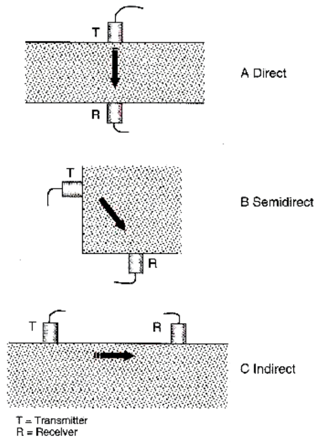


Figure 1: Pulse velocity measurement configurations

In this research, the indirect method was used in order to check the correlation between velocity pulse measurements and the laser intensity.
In the 3D-laser scanning, the travelling time of coherent light laser pulse is converted into the distance between the instrument and the investigated target. The outcome of a laser scanning campaign is a very dense cloud of points whose positions are known in a reference frame located in an arbitrary point inside the laser scanner. For each point of the surveyed target surface, the X-Y- Z coordinates and the reflectivity value are acquired and recorded, providing the area coverage necessary for the 3-D reconstruction and characterization of the surveyed area of interest or structure.
It has been found by Casula et al. (2008) that the changes in spectral frequency composition of the ultrasonic and 3-D laser scanner data seemed to be related to changes in stone material properties, 'but the relationship between frequency composition and rock-properties is not nearly as definitive'. Casula et al. (2008) concluded that further digital processing is needed for both ultrasonic and 3-D laser scanning data. Indeed, they found that petrophysical aspects are also required for further analysis.

2. CASE STUDY

The monument selected for the implementation of the presented non-destructive techniques, is known as the Limassol Castle (Figure 2). It is located in the south-west of Cyprus in Limassol District, in the historical centre of Limassol city. In its current form, the fortress is a result of a radical reconstruction done by the Ottomans after they conquered Cyprus in the 16th century A.D. A Part of the original medieval structure was incorporated into the one formed by the Ottomans. Part of the Castle has been used as a prison until the mid 19th century when it was given to the Department of Antiquities. Since 1987, the Castle is being used as the Medieval Museum of Cyprus.
The monument consists of regular masonry of limestone blocks commonly known as sandstone, a material frequently used for vast constructions in Cyprus, mainly because it is easily mined and elaborated. This material though is extremely vulnerable to deterioration due to its high porosity, especially when employed in monuments close to the sea, as the case presented.
In recent years the edifice received a number of conservation interventions as well as various modifications (c.f. Annual Report of the Department of Antiquities of Cyprus,) for several years, to adapt to its new use, that of a museum.

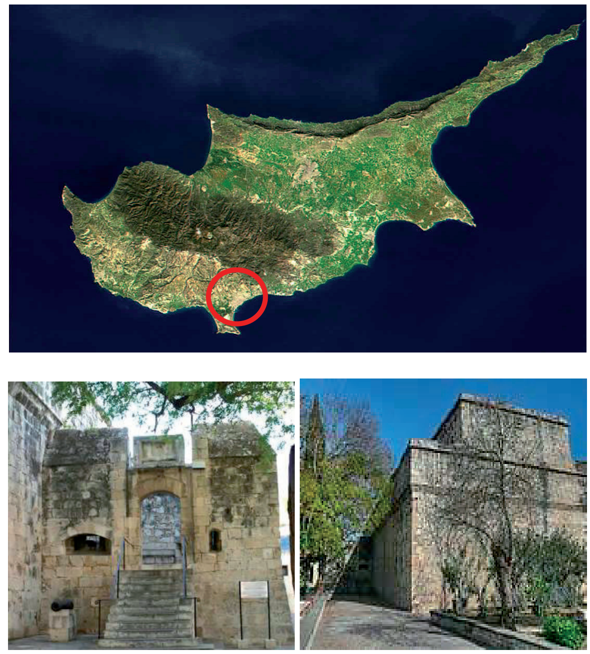


Figure 2: The Medieval Castle of Limassol

3. METHODOLOGY

3.1 Method

The overall methodology is presented in Figure 3. Ultrasonic-pulse velocity measurements have been acquired using the indirect method. Moreover the 3D laser scanner, LeicaScan Station C10 was used for documentation of a part at the north facade of the medieval Castle of Limassol. The readings were then post-processed and the first diagnostic results of the correlation of the two methods were obtained.

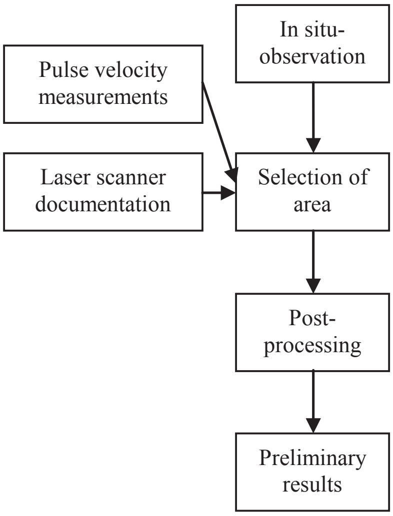


Figure 3: Methodology applied

3.2 Resources

For the application of the non-destructive techniques the following resources were used.

3.2.1 Pundit Plus Ultrasonic System: The Pundit Plus Ultrasonic system (Figure 4) is low frequency ultrasonic concrete test equipment for field or laboratory use, with data storage and computer output facilities. It enables the detection of cracks, voids and other imperfections in concrete and reinforced concrete. Pundit Plus is also used for quality control purposes, for testing concrete strength. It has a frequency range from 24kHz to 1MHz, while the pulse rate is adjustable from 1 to 100 per second.

Figure 4: The Pundit Plus Ultrasonic system used

3.2.2 Laser ScanStation C10: The terrestrial ScanStation C10 (Figure 5) has a 360º x 270º field-of-view window, high accuracy (less than 1cm), a long range (300m @90% reflectivity), and high scan speed (50 000 pts/sec).

Figure 5: The Laser ScanStation C10 used

4. IMPLEMENTATION

A part of the north facade of the medieval Castle of Limassol was selected as the first case study (Figure 6). A closed-range photographic documentation was carried out in order to archive in detail the facade (Figure 7). An area of 4 x 2.5 m was selected.

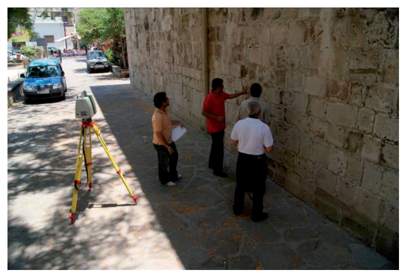


Figure 6: In-situ observation

Figure 7: Detailed photographic documentation

The area under investigation has been divided into a grid of 0.20 m width and 0.30 m length, as shown in Figure 8. This was done in order to assist our pulse-velocity measurements.

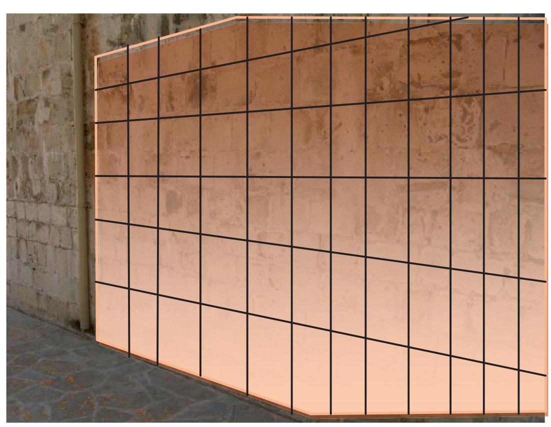


Figure 8: Grid division of the selected area

The measurements were carried out using the indirect method since it was not possible (due to the thickness of the wall) to apply the direct method (Figure 9).

Figure 9: Indirect method implementation

The next step was to carry-out the documentation of the wall. The laser scanner resolution was set in the medium resolution which corresponds to a grid of 1cm in a 10 m distance from the object (Figure 10).

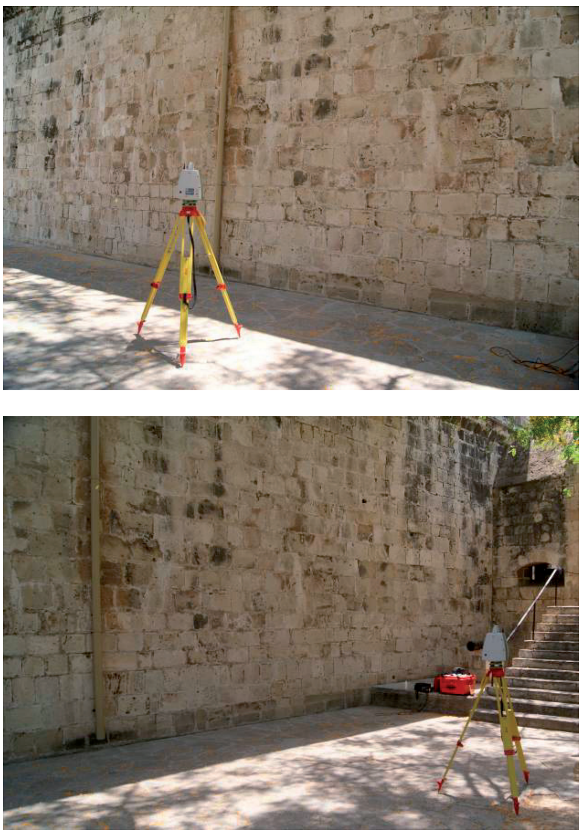


Figure 10: Laser scanning documentation

5. RESULTS

The in-situ observation records had given valuable information regarding the preliminary diagnosis of the wall. Free-hand sketches, digitized in CAD environment (Figure 11), may be used in a future work in a digital entity-relation database connected to a Geographical Information System for archiving, analysing and processing the data collected.

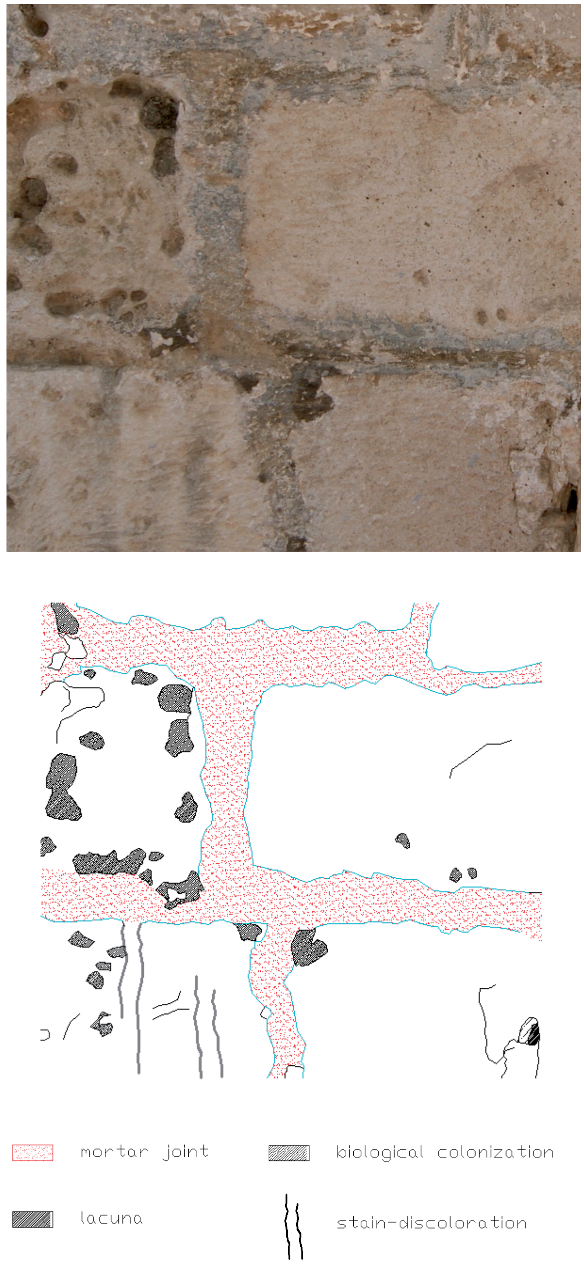


Figure 11: Preliminary deterioration diagnosis of the wall (through macroscopic observation)

The pulse velocity measurements were plotted in the Surfer environment in order to visualize the result (Figure 12).

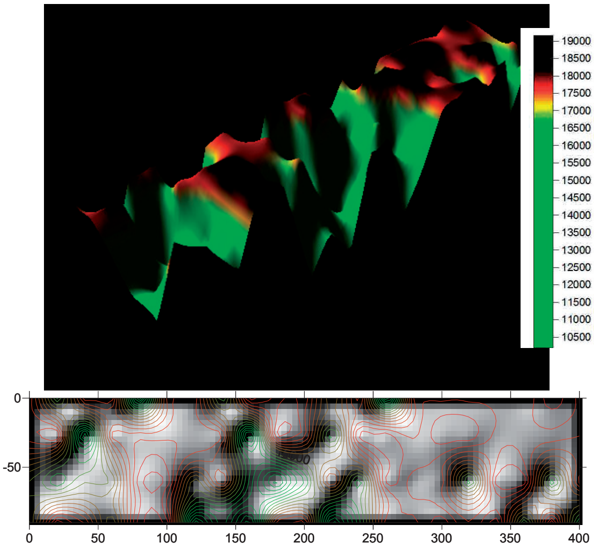


Figure 12: Pulse velocity measurements, presented in different forms in the Surfer software (X-Y axes are cm from the NW corner of the selected area)

Moreover the intensity of the laser was extracted using the Cyclone software (Figure 13). The advantage of the laser scanning intensity over images taken from a digital camera is that with the former a user can also obtain the geometry of the object measured.

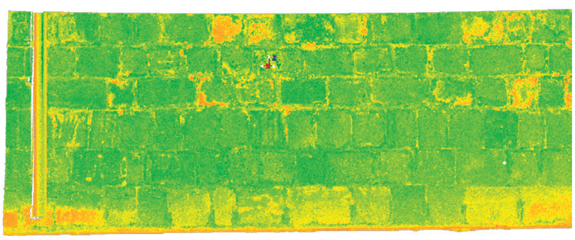
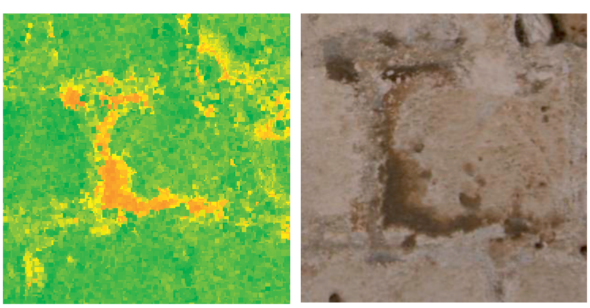


Figure 13: Intensity of the laser scanner

A direct visual comparison between the intensity of the laser scanner and the close range photographs is shown in Figure 14. Figure 15 presents the visual comparison between the ultrasonic measurements and the close range photographs while Figure 16 highlights the comparison between laser intensity and ultrasonic measurements.



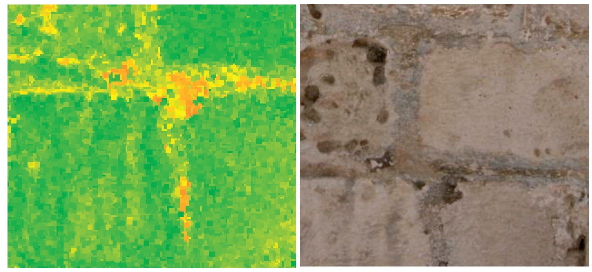


Figure 14: Visual comparison of the laser intensity and close range photographs

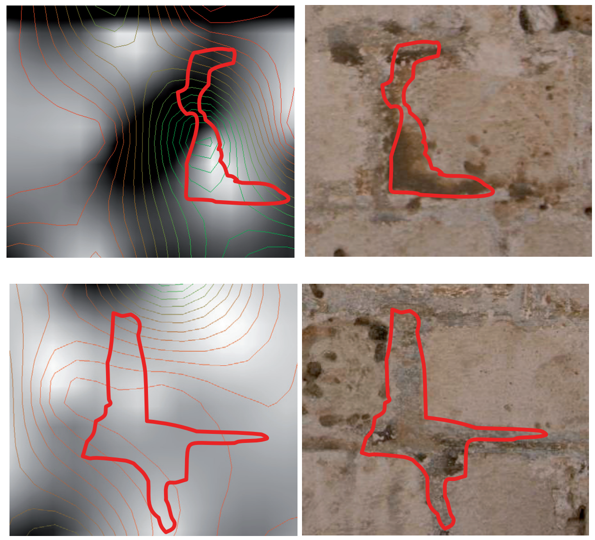


Figure 15: Visual comparison of the ultrasonic measurements and close range photographs. The polygons are drawn as common areas for each set of figures.

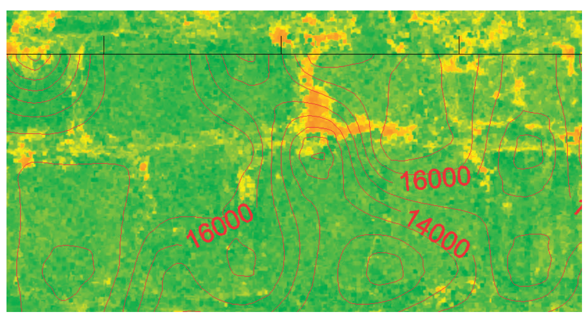


Figure 16: Visual comparison of the ultrasonic measurements laser intensity

In examining Figure 15 we can visually observe a concentration of the ultrasonic contours around the crack. The values of these contours are decreasing as we are getting closer to the crack which indicates the presence of a discontinuity. Similar conclusions can be drawn from Figure 16 which compares the laser intensity and ultrasonic measurements. In the area where green colour is obtained from the laser intensity, which indicates solid stone at least at the surface, the ultrasonic values are in the range of 16000. On the other hand, in the areas where a red colour is given by the laser intensity, which indicates a crack, lower ultrasonic values are obtained This suggests the presence of a discontinuity, since the time needed to travel the same distance between the transmitter and the receiver increases. Nevertheless, it should be pointed out, that the contours of the ultrasonic do not match exactly the laser scanner intensity results. This can be attributed to the fact that the ultrasonic grid is discrete, while that of the laser scanner is more or less continuous. This drives to the conclusion that a denser ultrasonic grid will most probably improve the correlation between the two methods. This will be further investigated in future field campaigns.

6. CONCLUSIONS

This project explores the beneficial use of both ultrasonic and 3D-laser scanning methods for evaluating and assessing the structural quality of building materials such as stones of cultural heritage structures. This technique may be a more appropriate choice as opposed to more time consuming, invasive and possibly destructive techniques currently used in archaeology. In this paper, a first attempt was made to correlate the results of 3D-laser scanning measurements with ultrasonic pulse velocity ones. The visual evaluation of these preliminary results has shown that there is a correlation between the two methodologies and that this method should be further investigated. Future research can focus on improving the measurement methodology and on substantiating the correlation between the two measurement methods. Further investigation with more field campaigns is required which are part of our future work.

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