COMPUTER VISION TOOLS FOR 3D MODELLING IN ARCHAEOLOGY

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ABSTRACT:

In archaeological Cultural Heritage study 3D modelling has become a very useful process to obtain indispensable data for documentation and visualization. Nowadays the continuous request to achieve photorealistic 3D models has led to testing different techniques and methodologies to speed up both data acquisition and the data processing phase. There are many examples of surveys conducted with the use of range-based and image-based techniques, but, in the last few years, the scientific research has been increasingly moving towards automatic procedures using Computer Vision approach to reduce time during data processing. Computer Vision approach offers a great opportunity for archaeological survey since it can be very easily used by existing Computer Vision interfaces such as 3D web services and open source or low cost software. The aim of this work is to evaluate the performance offered by Computer Vision interfaces for 3D survey of archaeological ruins using some 3D web-service tools and a low cost software like PhotoScan package. Some tests have been performed to analyze the geometric accuracy of 3D models obtained by 3D web-service tools and PhotoScan package through the comparison with a 3D model achieved by laser scanning survey.

1. INTRODUCTION

The study of archaeological Cultural Heritage has a valid support in new technologies offered by geomatics to create highly detailed and accurate 2D/3D products. Indeed in this field the construction of detailed 3D models for different types of representation and documentation is increasingly required in order to carry out analysis for restoration, for historical studies or simply for visualization. For these reasons, the research is increasingly directing towards the study of methodologies able to enhance the performance of the geomatics techniques and to reduce the time both in survey and in processing phase.

In Cultural Heritage documentation, and particularly in archaeology documentation, the survey techniques should have some properties such as accuracy, low cost, portability and rapidity of data acquisition (Remondino & Rizzi, 2010). Even if the range-based techniques are in general more accurate, the image-based techniques are more convenient and practical (Remondino& El-Hakim, 2006; Bitelli et al.; 2007, Barazzetti et al., 2011). Furthermore, the image-based techniques, through the use of algorithms derived from Computer Vision (CV), known as “Structure from Motion”, are able to automatically perform the whole pipeline reducing time both of images orientation and 3D reconstruction (Vergauwen & Van Gool, 2006; Barazzetti et al., 2011; Doneus et al. 2011;). The "Structure from Motion" approach allows to orient a very huge numbers of images without any knowledge of the camera parameters and network geometry (Barazzetti et al., 2010). The images orientation is performed automatically identifying the common feature points through appropriate interest operators. The SIFT (Scale Invariant Feature Transform) (Lowe, 2004) is one of more interest operator used in CV because it allows to find correspondences between images taken from different positions, with different scales and different illuminations. The camera parameters can be estimated during the matching phase (self–calibration). In the "Structure from Motion" approach all consecutive images are coupled and the subsequent image is matched with the previous pairs. Since all the images are matched together the whole epipolar geometry is reconstructed and thus the projective scene geometry. The results of this process are the camera parameters, the images orientation and a sparse point cloud of the object. These points are not useful to obtain a satisfactory reconstruction of the model but they constitute the basis for the subsequent phases of image matching, such as the dense stereo matching techniques, which allow to create a very detailed point cloud.

The "Structure from Motion" has been used in many applications like reverse engineering (Menna & Troisi, 2010) or UAV applications (Nietzel & Klonowski, 2011). Some interesting experiences have been done combining spherical photogrammetry and "Structure from Motion" tools (D’Annibale et al., 2011).

The "Structure from Motion" approach is used in many open source software (Bundler, CMVS/PMVS2), in some photogrammetric commercial packages (PhotoModeler 2012 by EOS Systems Inc., PhotoScan by AgiSoft LLC) and in many 3D web services (Autodesk 123D Catch, ARC 3D Webservice, Photosynth from Microsoft, Hypr3D). The 3D web services are web tools for remote 3D reconstruction; they allow the reconstruction of 3D models from images in a very short time and without any specific knowledge. These services are available online and are completely freeware. They are created for inexperienced users and mainly for visualization but they could be very useful especially in archeology field, where generally the campaigns have restricted budget.

Commonly, CV techniques aim more on process automation rather than on precision and accuracy (Barazzetti et al., 2010). This condition is disadvantageous when the purpose of the 3D survey is also a model with a good metric accuracy. Nevertheless promising results have been achieved for the survey of small objects using ARC3D (De Balestrini & Guerra, 2010), and of a prehistoric site using Autodesk 123Dcatch (Chandler & Fryer, 2011).

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The aim of this work is to evaluate the performance offered by the "Structure from Motion" approach for 3D survey of archeological ruins using existing CV interfaces such as some 3D web-services and PhotoScan package. Some tests have been performed to analyze the geometric accuracy for the creation of 3D models through the comparison with a 3D model obtained by laser scanning data. The tests have been direct to obtain a 3D model of the ruins of the archaeological site of Solunto; in particular, in this first stage we have only surveyed the ruins of the ancient Greek theatre. The ancient city of Solunto is situated on the north coast of Sicily, near Palermo, on the south-east side of Monte Catalfano. It was founded by Phoenicians in the VI century A.C.; later it became a greek colony and finally a roman colony. The city had a Hellenistic urban plan of “Hippodameic” type, where the three main centres, religious, administrative-political and commercial, were included in the layout of equal-sized blocks of buildings delimited by straight, often paved, roads with perpendicular intersections.

The theatre is located above the “agora” and it originally had a diameter of about 45 m and 21 orders of seats; the theatre could receive up to one thousand people (Figure 1). The orchestra has two overlapping floors dating in two subsequent phases: the former is probably of the VI century B.C., the latter of the Hellenistic period. Today only a little portion of tiers remains.

Figure 1. The theatre of Solunto

The first part of the article describes the laser scanner and the images acquisition; the second part reports the data processing. The 3D models were carried out using different 3D web-services (Photosynth, ARC3D, Hypr3D, Autodesk 123Dcatch) and a low cost commercial software (PhotoScan by AgiSoft LLC). In the last part of the article some comparisons have been performed to evaluate the quality and metric accuracy of the 3D models generated with image-based approach.

2. DATA ACQUISITION

The 3D survey of theatre of Solunto was conducted using topographic, laser scanning and image-based techniques. The topographic survey, executed by using a Leica 1105 total station from a single station point located in front of the theatre, was used to measure the coordinates of some laser scanning and photogrammetric targets. In this way we can refer all 3D data to the same reference system. The laser scanning survey enabled to cover the area once occupied by the “cavea” of the ancient theatre, while the photogrammetric survey covered only a little portion of the tiers of seating.

2.1 Laser scanning acquisition

The laser scanner survey was conducted using a FARO Focus^{3D} S120. This laser scanner uses phase shift technology and has a measuring range from 0.6 to 120 m (Figure 2).

Figure 2. Laser scanner survey

Five scans were executed from five station points: three under the “cavea” and two from the top of the “cavea”. Eight checkerboard targets were placed in the area of the theatre in order to merge all the scans in the same local reference system. The scans resolution was set with a step of 5 mm at a distance of 10 m. Finally the portion of the model representing the theatre seats was used as a reference model for the tests.

2.2 Images acquisition

The images acquisition was conducted in two different steps using a Nikon D80 digital camera equipped with fixed focal length lens of 28 mm with a sensor size of 23,6 mm x 15,8 mm (3872 x 2592 pixels) and a pixel size of 6.1 m. The first step was performed during the laser scanning data acquisition and the topographic survey. Five convergent images were taken from a distance of about 5 m. These images weren’t suitable for a 3D reconstruction, but they were used only to scale and to rototraslate the 3D web service models.

The second one was performed with a telescopic pole having a bayonet cap, where the digital camera was applied on top. The telescope pole is 2 m long when fully extended. The images were taken putting the pole at different heights: some of them placing the pole on the ground, others raising it to height more than 2 m high. The images were both convergent and stereoscopic and they were taken tilting the camera to obtain a set of images providing a good coverage of the object. Three stereoscopic strips were taken from three different heights: the first one from a height of about 2 m, the second one from a height of about 2,25 m, the third one from a height of approximately 2,50 m. A total of 25 stereoscopic images were taken from an average distance of about 4 m. The convergent images were taken from a height of 2,00 m and a distance of 6 m; totally 17 convergent images were taken (Figure 3).

The images taken during the second step were used to obtain the 3D reconstruction. They were captured one week after the first step; these images didn't have the photogrammetric targets (they were removed) useful for images orientation.

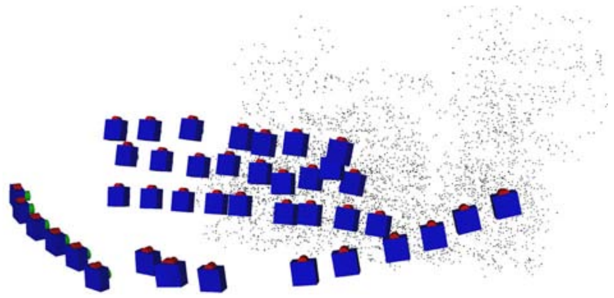

Figure 3. Camera network of images used for 3D reconstruction

3. DATA PROCESSING

3.1 Laser scanning data processing

The laser scanner data processing was carried out with the software Faro Scene and Geomagic Studio. In the first step every scan was registered and merged with Faro Scene software. Before the registration procedures a first editing was conducted by removing the external parts and those portions with presence of vegetation. The scans were aligned and registered to the global reference system using the eight targets obtaining a standard deviation of 4 mm. The point clouds were exported in ASCII and were processed using Geomagic. Some filtering was applied to remove noise, redundant points and outliers. Then all the scans were merged together. Finally a polygonal model ("mesh").of the theatre seats was created.

3.2 The Computer Vision tools

The image data processing was executed with the 3D web-services Photosynth, ARC3D, Hypr3D, Autodesk 123Dcatch and with the low cost commercial software PhotoScan.

Photosynth is a Microsoft web service which is accessible through a Windows Live account at the Photosynth website. It requires the installation of an application to allow the uploading of the images to the server. Photosynth enables to create two kinds of 3D products: panoramas and synths. The former stitches a set of images together taken from the same point to create a seamlessly panoramic picture. The latter creates a view that allows to browse from photo to another photo by using a set of overlapping images. This process was created especially for "Photo Turism" (Snavely at al, 2007), but it is also able to create a point cloud of the object. The camera calibration parameters, the images exterior orientation parameters and the point cloud can be exported through SynthExport applications (http://synthexport.codeplex.com) in different formats.

ARC3D (Automatic Reconstruction Conduit) is a EPOCH network tool for creating 3D models (point clouds and polygonal model) out of a set of images. The user must install a software to upload the images to the server. If the reconstruction has been successful the 3D model can be downloaded in different formats. The model can be displayed through the use of MeshLab, an open source software used for viewing and editing point clouds and 3D triangulated models. To obtain good results the images should be convergent with angle less than 10 degrees and large overlap.

Hypr3D works directly online with images or videos. The first step is the choice of file format to upload (images or videos). The second is the upload of the files, at least five images, that are useful for the creation of the 3D model. The process computes the camera parameters, produces a point cloud, a wireframe model and a texturing high-resolution model. The model can be downloaded in different formats and resolutions.

Autodesk 123Dcatch is a web service which is managed through a software downloaded from www.123dapp.com/catch. With this software it is possible to upload the images, to define the camera focal length and to modify the photo-scene after the first process. An important difference compared to the other web services is the equipment of some tools that allow to modify or to improve the result, e.g. the manual collimation of points to orient the images or to scale the model. Furthermore it is possible to set the origin and the axes of a global reference system. The final product is a triangulated surface which can be achieved in three different resolutions: mobile (fast medium resolution mesh), standard (high resolution texture mesh) and maximum (very high density mesh).
Recently two kinds of apps are available: the web app that allows to compute the 3D scene directly on line and the iPad app that enables to create and to view the 3D scene on iPads.

Agisoft PhotoScan is a low cost image-based package aimed to obtain high quality 3D model. The software is based on multi-view 3D reconstruction technology and can operate with calibrated and un-calibrated images in both controlled and uncontrolled conditions. The workflow includes fully automatic images orientation and 3D model reconstruction; the model can be exported for editing in external software. All the processes can be performed with different levels of accuracy and many parameters can be set to improve the final result. For our work we used the PhotoScan professional edition installed on a 32-bit system. This condition could limit the software performance especially when the product must be a high quality 3D model.

3.2.1 Images data processing

Microsoft Photosynth: The model created with Photosynth was performed using all stereoscopic and convergent images (42 images). The 3D web-service was able to orient all the images in a very short time. This is a big advantage when it is necessary to orient a large number of images. However the produced point cloud was very noisy and sparse, sometimes inadequate to obtain a detailed 3D model. Moreover a limitation of this web service is the absence of tools that allow to create a polygonal model (mesh). Overall about 120.000 points have been calculated. The points were imported in Geomagic to produce a polygonal model. The poor point cloud has allowed to obtain a 3D model composed by a number of triangles lower than that obtained by the other interfaces. The mesh was poorly defined with the presence of holes mainly in correspondence of the upper surfaces of the higher seats and in the lateral surfaces of the seats. An editing phase was necessary and a 3D model with about 230,000 triangles was achieved (Figure 4).

Figure 4. Photosynth 3D model

ARC3D: The experience made with Arc3D has highlighted some problems during the images processing. To obtain the 3D model several tests have been executed using different images block with different levels of re-sampling. The first test was performed using all the images without applying any images re-sampling. The 3D web-service was able to upload all the images, but the obtained model was incomplete. Therefore other tests were carried out using all the images and applying a re-sampling up to 50% of the original images resolution without obtaining satisfactory results. Other tests were performed with only the 25 stereoscopic images and only the 17 convergent images. The best result, a high resolution 3D model in regard to both the texture and the level of detail, was obtained using only the 17 convergent images without performing any resampling. The automatic process was able to reconstruct completely the surfaces of the theatre seats. There were holes only on the upper surfaces of the higher seats. The model was imported in Geomagic to perform some editing operation in order to obtain a complete 3D model composed of 390,000 triangles (Figure 5).

Figure 5. ARC3D 3D model

This experience has allowed to state that often the process can fail with this web service, when the used images don't meet the requirements for the processing. Furthermore it is not so simple to understand the problem of the process failure, so to obtain good results it is necessary to execute many tests. However when the 3D reconstruction has been successful, it is possible to obtain high quality 3D models in a short time.

Hyper 3D: Also with Hyper 3D some tests were performed with different set of photos to evaluate what kind of images is better to obtain a complete and high resolution 3D model. Three tests were carried out: the first one using all the 42 images, the second one using only the 25 stereoscopic images, and the last one using only the 17 convergent images. Hyper 3D was able to orient and to obtain a good 3D model with all the used datasets, but the 3D model obtained by the 17 convergent images was better than the others and it was used for the subsequent comparisons. A point cloud of about 150,000 points was obtained. As Photosynth and Arc 3D this web service doesn't have any tools to modify or to improve the obtained 3D model so the point cloud was imported in Geomagic to create a polygonal model. Some holes were present in less visible portions from the images. After an editing phase a mesh with about 220.000 triangles was obtained (Figure 6).

Figure 6. Hypr 3D model

Autodesk 123Dcatch: All images have been used with this web service and their orientation has been successful, but the obtained 3D model showed some imperfections, so to refine the orientation phase and to improve the 3D reconstruction it was necessary to measure manually some points. Indeed, after the first processing, it is possible to choose some points directly on the images to help the process orientation. This possibility is a great advantage, as it makes the user interaction possible to aid the 3D reconstruction. Another advantage is the opportunity to set the resolution of the mesh according to the aim of the survey. For this work the 3D model was computed with maximum resolution (very high density mesh). Any editing phase was performed as the 3D reconstruction appeared satisfactory and there were not holes. A polygonal 3D model was created with about 800,000 triangles (Figure 7). Finally a big disadvantage is the absence of tools that allow to check the correct orientation of the images, as will be seen below, this can create problems in geometric accuracy of the final model.

Figure 7. Autodesk 123Dcatch 3D model

Photoscan: The data processing carried out with Photoscan was executed using all the images (42 images). The images were automatically oriented performing a first orientation with a low level of accuracy and afterwards re-computing the orientations with a high level of accuracy. This packages is different from the previous tools, because it is a commercial software that doesn't work on line. Moreover it is possible to set the accuracy of every phase of the whole pipeline, from the images orientation to the 3D reconstruction. Several editing commands to modify or to improve the obtained 3D model are available, such as mesh decimation, removal of detached triangles, closing of holes, etc. Photoscan is able to produce a 3D model with very high geometry resolution, but, to obtain this, it is necessary to have a high-performance workstation. Consequently the resolution of the obtained 3D model has been limited by the used hardware. Therefore in our case it was possible to compute a 3D model with a medium target quality and imposing a maximum limit of 400.000 triangles (Figure 8). The obtained level of detail was considered sufficient for this work.

Figure 8. Photoscan 3D model

4. METRIC ACCURACY EVALUATION

In order to evaluate the metric accuracy of the 3D models a comparison was performed using the laser scanner 3D model as reference.

The workflow was:

- to scale the web service 3D models using a reference distance;
- to align the web service 3D models in the global reference system;
- to compare laser scanner and web service 3D models.

To scale the web service 3D models some reference distances were measured from a photogrammetric project done with Photomodeler Scanner using the first set of images, containing the photogrammetric targets surveyed with the total station. Photosynth, Arc3d and Hypr3D models were scaled adding directly on the 3D models a distance between two points; Autodesk 123D catch model was scaled adding a distance directly on the images. The alignment of the web service 3D models in the same reference system of the laser scanner 3D model was performed with Geomagic through the ICP (Interactive Closet Point) registration algorithm.
The Photoscan 3D model was scaled and georeferenced in the global reference system identifying four markers on the images. The markers coordinates were computed through the photogrammetric project of PhotoModeler Scanner.
The third phase was conducted with the software Geomagic to perform a 3D comparison between the surfaces of web service models and laser scanner model.
The standard deviations resulting from the comparison with the models obtained with Arc3D and Hypr3D are 0,012 m while those resulting from the comparison with the models created with Photosynth and Photoscan are 0,014 m. The worst result was achieved with Autodesk 123Dcatch; the standard deviation resulting from this comparison is 0,026 m.
A 3D map, that shows the distribution of deviations between the different models through a color scale, was created for each model; the deviations represent the shortest distance from the reference model in 3D. The distribution of deviations is not uniform for all the models. The 3D maps of Photosynth, Arc3D, Hypr3D, and Photoscan show that the maximum deviations are ± 0,06 m and they are situated in critical areas such as the interstices among the stones of the seatings, where the data appears noisy, and the border areas, that are not visible on the images (Figures 9 - 12).

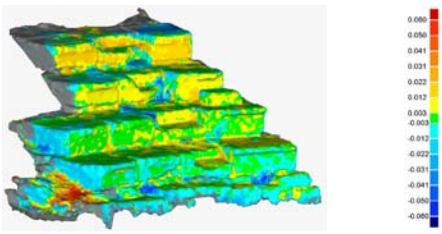

Figure 9. The 3D map of the comparison with Photosynth

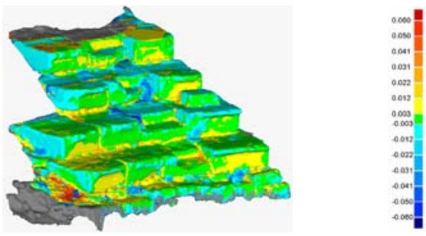

Figure 10. The 3D map of the comparison with Arc 3D

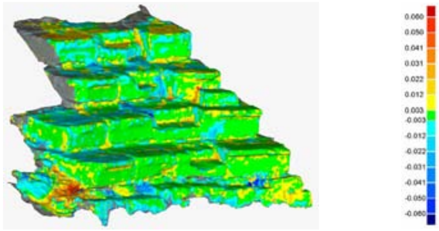

Figure 11. The 3D map of the comparison with Hypr3D

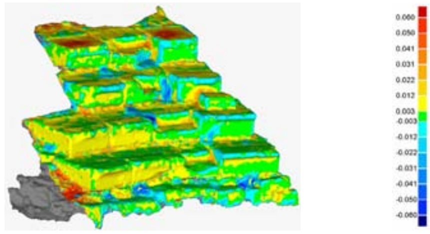

Figura 12. The 3D map of the comparison with Photoscan

Furthermore grey areas represent the portions where the two model don’t match. These areas are mainly situated where the models had some holes that were filled manually.
The model showing the worst result was achieved with 123Dcatch. There is an odd distribution between the positive and negative values of the deviations both among seats of the same row and among seats of different row (Figure 13). The front surfaces of the seats in the two lower orders have positive deviations in the outer parts and negative deviations in the inner parts. This could indicate a problem on the correct geometry of the 3D model. Furthermore in the two upper tiers the deviations are for the most part negative.

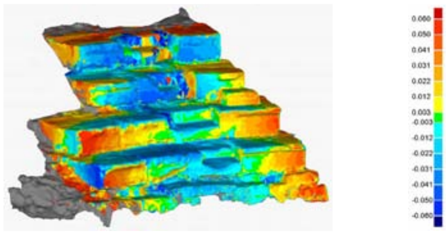

Figure 13. The 3D map of the comparison with Autodesk 123Dcatch

5. CONCLUSION

The experience described makes it possible to offer some considerations about advantages and disadvantages on the use of some CV interfaces for 3D survey in archaeology. The 3D web-services and PhotoScan package used for this work are promising tools to use in 3D survey of cultural heritage when there are short time and a limited budget.
Indeed the research showed that these instruments create 3D models with high resolution in a easy way and at low cost, but the automatic procedures are difficult to control due to the lack of tools able to check the 3D reconstruction. Sometimes the process can fail when the used images don’t meet the requirements for the processing, for example in the experience executed with Arc3D where it was necessary to perform several tests to obtain an acceptable result. Furthermore the absence of editing commands that allow to scale and to georeference the 3D model directly in the web services is a big disadvantage. Only two among the used CV interfaces allow some editing

operations: Autodesk 123Dcatch and Photoscan. The first one has some tools that allow to perform some limited editing operations, while the second one has several editing commands. Moreover another disadvantage is the absence of parameters to verify the correct images orientation.

The standard deviations obtained from the comparisons show a centimeter accuracy that is too low for high accuracy applications. The 3D maps resulting from the metric evaluation show an uneven distribution of the deviations. This could be due to problems of scale and/or of an incorrect alignment between the web-service 3D models and the laser scanner 3D model. Some problems noted in the 3D model created with 123Dcatch could be due to the incorrect images orientation.

However these applications are useful but don't always yield a correct 3D reconstruction. The high photorealistic quality allows to use web service 3D models in archaeology mainly for visualization, documentation and multi-temporal studies. Surely these tools cannot replace laser scanning or photogrammetric techniques when it is necessary to have 3D models with high level of accuracy. Further tests should be done using different datasets to evaluate the real performance of these applications and to study some simple procedures to check the metric accuracy.

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UAV SYSTEMS FOR PHOTOGRAMMETRIC DATA ACQUISITION OF ARCHAEOLOGICAL SITES

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KEY WORDS: UAVs, Photogrammetry, Archaeology, Computer Vision, DSM, Ortho image

ABSTRACT:

The use of UAV systems for surveying archaeological sites is becoming progressively more common due to the considerable potential in terms of rapidity of survey, costs and accuracy. The paper presents the first results of the photogrammetric survey of the archaeological site of Himera in Sicily (Italy) using by UAV systems. A complete documentation of the site through the production of a DSM and an ortho image were carried out. The research further evaluated two different image processing workflows: a typical photogrammetric approach and a computer vision approach. An ortho image of the archaeological site with a very high resolution was obtained.

1. INTRODUCTION

The documentation and preservation of archaeological sites often require the development of fast and easy techniques for 3D data acquisition, also in difficult conditions. Close range photogrammetry and terrestrial laser scanning are the most common techniques used. These techniques made it possible to obtain a high level of detail and accuracy and result to be very effective, especially for small or medium-extension archaeological sites (up to tens of hectares). However, for large archaeological sites close range photogrammetry and terrestrial laser scanner are not always the most suitable survey techniques; whereas, the information obtained from aerial or satellite images provide an overview of the study area, which is fundamental for the interpretation of archaeological structures. In fact, images obtained by metric aerial cameras (film and digital) or by high resolution satellite sensor have been used in archaeology for long (Cowley, 2011). It should be pointed out that such images have some limitations linked to the geometric resolution (typically of some decimetres and inadequate for detailed studies), to the periods of acquisition (which does not always correspond to a given particularly useful date for the purposes of the archaeological work), and ultimately to the cost.
In the last years small UAVs (Unmanned Aerial Vehicles) have become standard platforms for large-scale aerial mapping of areas at limited extent. Many tests have been done to verify the photogrammetric aspects and their potential applications (Haala et al., 2011; Eisenbeiss & Sauerbier, 2011). In particular, the performances of these photogrammetric systems are very high above all for aerial survey of archaeological sites (Eisenbeiss et al., 2005; Chiabrando et al., 2011; Hendrickx et al., 2011).
Beyond the acquisition phases, the image processing phase remains an unexplored topic as it should clearly defines the real capabilities of these systems for photogrammetric data collection and for archaeological survey.
In order to evaluate the UAVs workflow, some tests were performed for the study of the archaeological site of Himera (Sicily, southern Italy) using by close-range aerial photogrammetry techniques with micro UAVs. The main purpose was to obtain, besides the photographic documentation, a Digital Surface Model (DSM) and an ortho image of the site. The work was used to test different image processing workflows. The images were processed with both typical photogrammetric and computer vision approaches in order to identify the more efficient process. The two different approaches were compared in relation to the accuracy and automation of orientation and to the quality of photogrammetric data production.
The adopted pipeline was composed of different step like automatic flight planning, image orientation, image matching and DSM processing, ortho image generation.
The UAVs survey was allowed to acquire the data to extract a DSM and an ortho image of the site with a very high resolution and good accuracy.

2. STUDY AREA

The studied area corresponds to the higher part of the Himera archaeological site. The ancient city of Himera was situated on the coast of northern Sicily, about 30 kilometres far from Palermo. Himera, along with Selinunte, represents the western limit achieved by the Greek colonization. The first known settlement of Himera dates back to the VII Century BC; until its destruction (409 BC), the city extended to cover a surface of about 100 hectares.
The ancient urban area was built on a very complex landscape which included an area at the sea level (Lower Town) and a higher one (Upper Town); the Upper Town was located in a upland, named Himera Plane.
The work focused only on the Upper Town, where it is still possible to recognize two main groups of buildings: the "Northern Quarters" and the Sacred Area of the *Athena Temenos*. The "Northern Quarters" cover a surface of about four hectares and host the ruins of regularly shaped buildings; the Sacred Area of the *Athena Temenos* hosts four temples and is bounded by a perimeter wall.

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3. DATA ACQUISITION

The aerial photogrammetric survey on the Himera site was realized using as carrier a microdrone md4-200 remotely piloted quadricopter. This carrier is equipped with four independent brushless electric motors and is able to fly up to 20 minutes at a maximum height of about 150 m (Table 1).

Load capacity (kg)	0,2
Weight (kg)	0,9
Diameter (cm)	70
Operation range (m)	500
Maximum relative height (m)	150
Flight range (min)	20
Engines	4 x 250W flatcore brushless
Camera	Pentax Optio A40
GPS	Yes
Auto-pilot	Yes

Table 1: Technical specifications of md4-200

The quadricopter is radio controlled by a human operator, so the operation range is mostly limited by the reach of the radio control. Md4-200 electronic equipment includes an Inertial Measurement Unit (IMU), a GPS antenna and a communication system, which allows a ground based station to receive telemetry data from the carrier and video signals from the onboard sensors. Furthermore, an onboard Flight Controller device permits to autonomously execute automated flights. Automation includes route and all the issues related to image (or other kind of data) acquisition (such as: carrier attitude, camera orientation, zoom level). This feature is of particular interest in photogrammetric applications since it allows the design of flight plans with the desired forward overlap and side overlap. Thanks to the GPS antenna, flight planning can be designed on geospatial basis. This procedure can be executed in a software (mdCockpit) provided by the carrier manufacturer or, as in this case, in an external GIS environment. Owing to the low load capacity of the quadricopter, the system is equipped with a 12 Mpx compact consumer camera (Pentax Optio A40) slightly modified to be mounted on the bottom of the carrier.
The data acquisition workflow of the Himera site was composed by the following steps:

- Preliminary study of the area;
- Flight planning;
- Survey execution.

The "Preliminary study of the area" was subdivided in an identification of the site on cartography (mostly small scale maps and orthophotos), which was included in a GIS project, and an *in situ* inspection for the location of all possible problems for the flight (obstacles, physiography, electric cables, etc.).
For the "Flight planning" the archaeological site was divided in two parts: a larger area (about 135 m x 285 m), corresponding to the highest part of the ancient inhabited town (Upper Town) and a smaller one (about 35 m x 60 m), that includes the remains of the religious building of *Athena Temenos*. Owing to the limited autonomy of the drone, different photogrammetric flights were planned to cover the entire area. The Upper Town was covered by three flights at a relative height of 100 m, while for the *Athena Temenos* was designed a single flight at 20 m from the ground surface (Figure 1). The "Flight planning" was performed in GIS environment and resulted in a code to be uploaded on the Flight Controller.

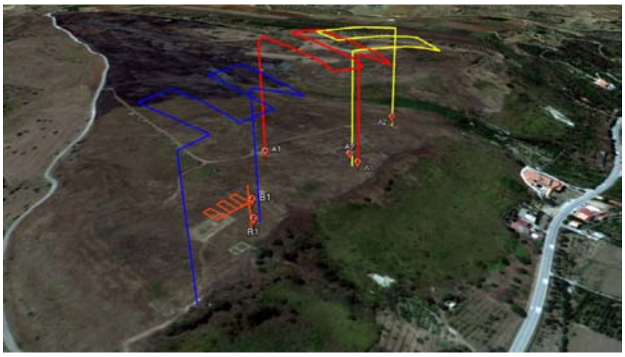

Figure 1: Flight planning

The images acquisition was executed setting the camera to its maximum resolution (12 Mpx) and using a focal length of 7.9 mm (Table 2).

Pentax Optio A40	
Focal length	7.9 mm
CCD Width	7.6 mm
CCD Height	5.7 mm
Pixel size	1.9 µm
Shutter time	1/1000
Aperture	2.8

Table 2: Camera parameters

With these parameters the Ground Sample Distance (GSD) was about 2.4 cm, for the flights from 100 m, and 0.4 cm, for the flight from 20 m. Image forward overlap and side overlap were set to 80% and 60%, respectively (Table 3).

	Flight height above ground	
	100 m	20 m
Forward overlap	80%	
Side overlap	60%	
GSD	2.4 cm	0.4 cm
Ground coverage per image	96 m x 72 m	19 m x 14 m

Table 3: Planned flight parameters

Regarding the "Survey execution", the flights were executed in autonomous mode, following the predefined flight path. This mode is the most useful for photogrammetric data acquisition. Images acquisition was performed in "stop mode"; the UAV system flies to a predefined way point and stops at its location to acquire the image (Eisenbeiss & Sauerbier, 2011). For every way point three images were acquired to assure the adequate data redundancy.

Before executing the flights, 30 targets, to be used as Ground Control Points (GCPs) during the image processing, were distributed along the area. A topographic survey was carried out to measure the coordinates of the targets using a Leica TCR 1105 total station. From a single point station, all the targets in a local reference system were measured. The accuracy of the target coordinates was estimated about 1÷2 cm. Subsequently, two targets were measured additionally by a static GPS surveying with a Topcon Hyper Pro using as master station a permanent station of the University of Palermo GNSS Network. These two last points were used to convert the coordinates from the local reference system to global reference system WGS84-ETRS2000 datum (UTM projection). The conversion was performed through a translation and a rotation of all the targets. No scale factor was applied during the coordinates computation to not introduce to the result all deformations of the cartographic projection. The cartographic height was obtained adding the difference between the height in the local reference system and the height in the WGS84-ETRS2000 datum calculated for one GPS point to all targets.
Flight execution lasted about two hours and produced 165 images at 100 m and 48 images at 20 m.

4. DATA PROCESSING

The flights with micro UAVs are usually planned following the typical aerial flight where all images are acquired with a nadir view. This condition may not always be obtained with micro UAVs flight, because the short weight, the line and the attitude of flight can be modified by the wind.
The first phase of data processing was dedicated to the identification of the most suitable images for the work. In particular, it has been first verified the forward overlap and the side overlap. The figure 2 shows an example of a sequence of three images taken from the same waypoints; it can be noted that, even if the images were taken in a very short interval of time (few seconds), significant displacements of the camera may occur.
Besides, using consumer digital camera and in the absence of any device able to compensate for the movement of the sensor during the acquisition, the radiometric quality of the images can be degraded. This can affect both the automatic autocorrelation process and the manual photogrammetric measurement.
Therefore, the presence of images particularly blurred has been verified; the figure 3 shows a sequence of three images, taken by the same way point, where the image quality degrades considerably due to this effect.
The redundancy of images for each way point, however, has allowed the selection of a data set with the best characteristics as regards the block geometry and the radiometric quality. Overall 58 images were selected for flights from 100 meters and 17 images for the flight from 20 meters. Each flight from 100 meters was consisted of a photogrammetric block of three strips; two blocks had direction north-south, the third east-west. The flight from 20 meters had four strips and direction north-south (Table 4).

Figure 2: Sequence of three images taken from the same waypoints with significant displacements of the camera

Figure 3: Sequence of three images taken by the same way point in which image quality degrades considerably.

Flight	Height above ground	Images	Strips	Direction
F179	100 m	23	3	North-South
F180	100 m	20	3	East-West
F182	100 m	15	3	North-South
F183	20 m	17	4	North-South

Table 4: Photogrammetric block configuration

4.1 Camera calibration

A fully automatic self-calibration was carried out in laboratory using iWitness Pro software and 20 black & white coded targets to determine the interior orientation parameters of the camera.
The camera was set with the same parameters to be used during the flights: focal length fixed at minimum zoom (widest angle), focus fixed to infinite. The coded targets positioned to form a 3D calibration grid (Figure 4).
A network of 20 convergent images was taken from each side and from the diagonal of the grid. The network included also images with ±90º roll angles. Through the camera calibration the principal distance (c), the principal point position (xp, yp) and the radial distortion coefficients (K1, K2, K3) were calculated (Table 5).
For more accurate results, the camera calibration parameters should be obtained under conditions that are similar to the photogrammetric survey. This approach is not simple for UAV project because it requires a suitable test field and flight plan. Moreover, using consumer digital camera the overall accuracy obtained with lab calibration parameters and field calibration parameters are similar (Pérez et al. 2011).

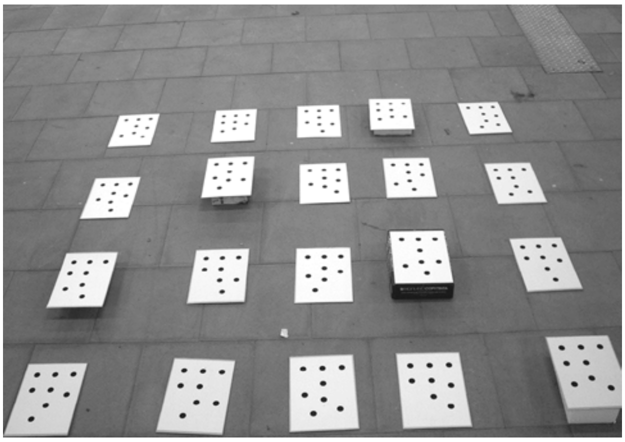

Figure 4: 3D calibration grid for camera calibration.

Parameter	Value	Stand. dev.
c	8.765 mm	0.001 mm
xp	-0.054 mm	0.001 mm
yp	0.019 mm	0.001 mm
K1	2.07420e-003	1.9049e-005
K2	1.69550e-006	2.4102e-007
K3	-6.61121e-007	9.1445e-008

Table 5: Camera calibration parameters.

4.2 Images orientation

In UAV projects, the images processing is still a topic of great interest as shown in several papers; not always the traditional photogrammetric systems are the most effective. Due to the various problems that may occur during the acquisition phase (irregular block geometry, poor radiometric quality) "not all software packages could be used in all possible applications of UAV photogrammetry; quite often, only the combination of several packages enabled us to completely process the data set" (Eisenbeiss, 2009). Some studies have been conducted to verify the possibility of using free and low cost software solutions (Neitzel et Klonowski, 2011), others to develop integrated procedures of computer vision and photogrammetry for fully automatic UAV image orientation (Barazzetti et al., 2010). In some applications, it was used an approach by the computer vision techniques to obtain orientation data and surface model to use as input for photogrammetric packages (Haala et al., 2011; Rosnell et al, 2011).
In this work the Flight F180 (Table 4) was used as dataset to test the different image orientation realized using two approaches: photogrammetric and computer vision techniques.
The photogrammetric orientation was carried out with the software Socet Set by BAE Systems; this package is one of the most popular software for the processing of aerial images.
For the photogrammetric image orientation the camera calibration parameters, previously calculated with iWitness Pro, were used. The approximate microdrone position and orientation data, provided by the GPS/IMU, were also used; in this way it was possible to reconstruct the photogrammetric block configuration.
An automatic aerial triangulation (AAT) was performed by the routine APM (Automatic Measurement Point) of the software Socet Set selecting a tie point pattern with 25 points per image distributed uniformly under a regular grid. Overall 776 image coordinates were measured obtaining automatically 82 tie points. The automated process required a phase of manual editing to correct some false matching. A quality check on some points showed that the poor stability of the microdrone produces images with very different perspectives of the same point (Figure 5).

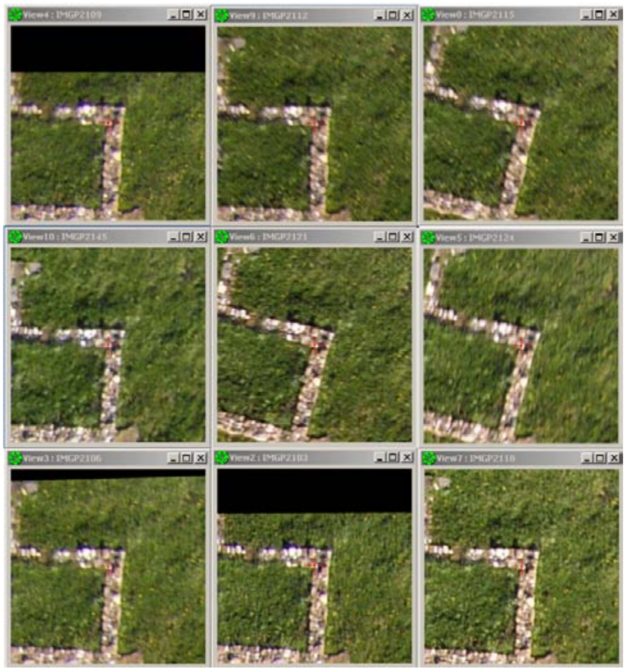

Figure 5: A tie point in several images

The exterior orientation parameters were computed using 8 GCPs; the control points were measured in semi-automated mode, identifying manually the target on an image and automatically by searching in all other through image matching.
As shown in figure 6 the position of the control points was not suitable, however through a rigorous bundle block adjustment

was possible to calculate the exterior orientation parameters obtaining a RMS for images residuals of ±1.4 pixel and for GCPs residuals of ±4.7 cm, ±3.7 cm and ±4.6 cm in the X, Y and Z directions respectively.

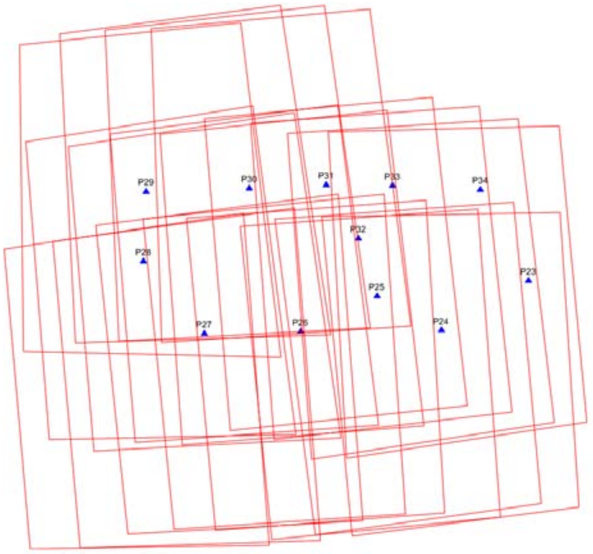

Figure 6: Block configuration and GCPs

Computer vision techniques was applied using the PhotoScan software (by Agisoft LLC) which is a low cost image-based package aimed to obtain high quality 3D model. The software is based on multi-view 3D reconstruction technology and can operate with calibrated and un-calibrated images in both controlled and uncontrolled conditions. The general workflow includes the fully automatic image orientation and 3D model reconstruction. All the processes can be performed with different levels of accuracy and many parameters can be set to improve the final result.

For lens calibration, PhotoScan software uses a pinhole camera model in the typical formulation of computer vision and, like all the computer vision applications, while carrying out photos alignment estimates both internal and external camera orientation parameters, including nonlinear radial distortions. For this reason, the camera calibration parameters previously calculated were not used.

With PhotoScan the automatic orientation was performed in various steps, with increasing accuracy. In a first step the images orientation was calculated with a low accuracy: the process oriented the 20 images of flight F180 in 4 minutes computing about 10000 tie points. Subsequently, the orientation was re-calculated with a medium accuracy obtaining about 54000 tie points in 7 minutes. Finally, the calculation was performed with the higher accuracy setting; a total of about 100000 tie points were determined in less than 10 minutes. The processing time, although with a much bigger number of points and with the higher accuracy setting, was much shorter than those obtained with the software Socet Set (about 15 minutes). It is important to note that the computation time depends on the PC characteristics, thus the previous information was reported to evidence the increase of computational load. In particular, for this work a PC with 32-bit Windows XP, a processor with 2.4 GHz and 4 GB of RAM was used. These characteristics, especially the 32-bit operation system, could affect the performance of the software.

The image orientation was obtained in a local reference system and in an arbitrary scale. The software do not provide any accuracy information about the image orientation. The camera parameters calculated during the self calibration were different in comparison with those obtained with lab calibration using iWitness Pro.

The photogrammetric targets were manually measured to transform the image orientation in the global reference system (WGS84-ETRS2000 datum - UTM projection). Assigning the cartographic coordinates to the targets, the photogrammetric block was referenced in the global reference system through a 3D transformation (3D translation, 3D rotation and a scale factor). Nine markers were used to compute the parameters of the 3D transformation obtaining a RMS of ±2.5 cm, ±1.5 cm and ±2.4 cm in the X, Y and Z directions respectively.

4.3 DSM and Ortho image generation

A DSM and an ortho image were calculated with the two software after the images orientation.

With the software Socet Set the module NGATE, that performs image correlation and edge matching on each image pixel, was used. The DSM was calculated in a regular grid with a resolution of 50 cm by selecting the best images in relation to the radiometric characteristics and to their Base/Height ratio (Figure 7).

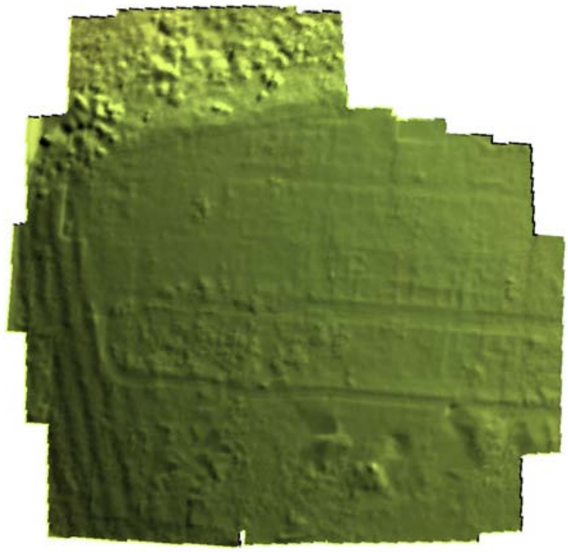

Figure 7: DSM obtained with Socet Set

Using the software PhotoScan it was not possible to define a geometric resolution of the DSM but the level of detail was chosen regarding the parameter "Target quality" (Ultra High, High, Medium, and Low, Lowest) and of the maximum number of faces in the final mesh. A "Target quality" medium and a maximum number of 200000 faces for the mesh were set for our work. The calculation of the DSM has allowed to obtain a surface with a point's resolution ranging from 20 cm to 60 cm (Figure 8).

With both software were made of the ortho images with a geometric resolution of 5 cm. Only with Socet Set it was possible to select the best images for ortho image generation. A qualitative comparison between the two ortho images has showed no noticeable differences (Figure 9).

For this reason, to obtain the data of the whole archaeological site, all the images were processed by computer vision approach with the software PhotoScan and the same workflow used for the flight F180. In this way processing time was significantly reduced. The figure 10 shows the ortho image obtained for the archaeological site of Himera by the flights from 100 meters.

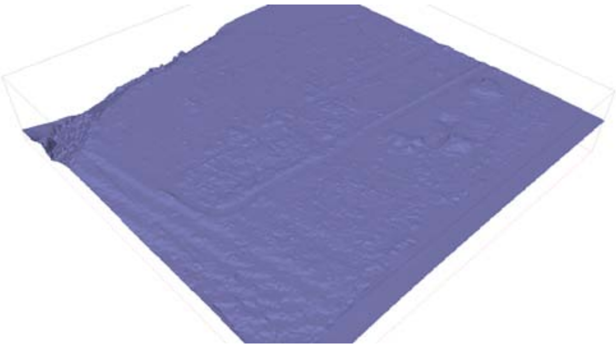

Figure 8: DSM obtained with PhotoScan

Figure 9: Visual check between the ortho images made with PhotoScan (in B&W) and made with Socet Set (in RGB)

Figure 10: Ortho image of the archaeological site of Himera

5. CONCLUSIONS

The use of UAVs for the aerial survey of the archaeological site of Himera evidenced the high performance of these systems. Some problems could occur during image acquisition, however with a very high redundancy of images a DSM and an ortho image suitable for large scale mapping with very high resolution and accuracy can be obtained.

The computer vision technique has proven to be more simple and more fast than the photogrammetric one, though the last is a rigorous approach. For this reason the computer vision approach can be used on the survey of the archaeological sites; and further tests should to be performed in different locations with difficult morphological conditions to evaluate the real performance of UAV systems for rapid and accurate data acquisition.

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THE “TERME DEL CORALLO” IN LIVORNO, ITALY, A CONTRIBUTION TO TRY GOING BEYOND THE ABANDON

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KEY WORDS: Baths, Livorno, Italia, Italy, Abandon, Terme, Liberty, Art Noveau, Photogrammetry, Digital Survey

ABSTRACT:

In Livorno, along the Mediterranean sea, in Italy, there is a terrific case of abandon, a historical monument made of fine art elements left to complete decay. The name of the place is “Terme del Corallo” and at its beginning it was a bath area exploiting the salt waters. After its first abandon, no serious efforts were done in years to come behind this situation, the poor and slow moves towards the restoration were stopped and slowed down by inefficiencies and infinite political considerations. The monument is now on the edge of collapse, showing a full failure of cultural preservation. According to this visible shame, a compact, almost viral, approach was started one year ago, entering the area in official (and less official) moments, a photogrammetric, photographical and direct survey was taken to document the condition of this monument. Further research was aimed to integrate and enhance the existing (poor) survey drawings and developing a restoration hypothesis recover to a solid, realistic and effective life to the whole monument. This paper will present the work made and the procedures, processing and results came out from this direct approach to this badly abandoned monument. The aim is to put in evidence this wrong situation, and to promote a sensitization about the correct choice to be taken for this monument before this rare artistic place from the XX Century will get completely lost.

1. THE “TERME DEL CORALLO” BUILDING

1.1 The “bath age” in Italy

Italy is one of the most important country for bathing-places in the world. Baths represent historical and cultural characteristics of a territory and one of the factors in social valuation and costumes. For example the “Thermae” and “Balnea” during the ancient roman period were centres for social life; or we may think about the “elite thermalism” during the beginning of the past Century .

The thermal bath was always strictly linked to the changes in the asset of a city. In time these buildings became part of the monumental and architectural heritage.

The first medicine treatise was “Corpus Ippocratium” written by Ippocrate, it's a meaningful text about the property of thermal water in human care. The phenomenon of thermalism had a big growth in ancient Rome. During the period of middle-age one of the first thermal baths was the “Acque Albule” in Tivoli, and the “Acque di Chianciano” in the homonymous town; the “Thermae” in the gulf of Naples; finally Pozzuoli and Ischia, two more places where it's possible to find important ruins of historical baths.

During the period of middle-age baths lost their social value in its hedonistic aspect, but the use of thermal water for human care had a large growth. In the period of Renaissance many writers testified about the thermal water qualities ,but the important discoveries end enhancements in this period were less relevant than in the middle-age period.

During the period between the XVIII and XX Centuries, thermal baths have an exponential growth and several new buildings were built. The thermal baths in this phase became a more complex system, receiving new functions like: hotels, café, garden, and mixing the classical scheme from the roman age with spaces coming from the oriental tradition. In this way the thermal baths became again a luxury place for a new elite thermalism. The Art Noveau architecture (called “Liberty” in Italy) was really popular during that time among rich middle-class and so became also the most used style for this kind of buildings. Today the architecture of the thermal baths are a union of luxury spaces with classical and modern thermal medicine. The result is a building where human health, wellness, beauty and fitness collaborated for a large system with continuous innovations and research in technology solutions.

1.2 The beginning

The “Acqua della Salute “ in Livorno born along the “Viale dei Condotti”; there are two different stories about the discovery of that curative water: legends and historical events. The legend tells: once upon a time in that plot of land emerged on the surface an unknown water and some cattle while grazing in this area have drunk the water and were afflicted by dysentery.

Figure 1: The “Terme del Corallo” before the abandon

After this fact the owners of that land decided to seek for the water. History tells that in 1854 there was a dry spell, and the families of the owners were in need of more drinkable water

because of their growth. After two excavations they found water and the scientific tests proved that the water was drinkable and had purging features.
In the 1865 along the "Viale degli Acquedotti" the owners of another area, excavated the land and found a different water and they named it "Acqua del Corallo" (water of the coral). During the period from the 1854 to the 1893, six different kinds of water were found, the curative property of these waters became famous; the hospitals near Livorno started using the waters for medical treatment. The popularity of the waters was the beginning for a new company, created by a group of persons with a robust fortune behind them, the name was "Società delle Acque della Salute" (literally: "The Health Water Company"). The company decided to protect the water in the ground building an underground system of walls; in the 1903 they decided to entrust Angiolo Badaloni with the task of realizing the new building named "Stabilimento delle Acque della Salute" (literally: "the Health Water Establishment").
The inauguration of the building was a grand event, people from far away went to visit the Art Noveau building. Livorno was decorated, citizen could appreciated and visit the thermal baths. Livorno during this period became a popular place for human-care with thermal water and was indicated as "Montecatini a mare" (Literally "Montecatini on the sea") with a direct recall to the name of "Montecatini Terme" a very famous town in Tuscany for its thermal baths.
The life in "Montecatini a mare" was studied from morning to evening; people spent in the "Stabilimento delle Acque della Salute" 15/20 days, according to the treatment agenda. In the complex it was possible to have different activities, some kind of entertainment and to relax.

1.3 The abandon

About the events that caused the closure of the complex, there is not certain information. The building worked until 1936, the Second World War was one of the main cause. Livorno was strongly damaged by bombing, in the centre of the city remained safe only the 8% of buildings, while in the suburbs of 43% buildings were saved.

Figure 2: Entering the dance hall. Today.

The "Stabilimento delle Acque della salute" wasn't hurt, but obviously the affluence was strongly reduced.
Immediately after the Second World War there was an increase of the population caused by the return of soldiers, so in the 1947 the local Administration bought the area in the east side of the city and started to build housing.
This big growth of the city in this area (in the surroundings of the thermal baths) probably cause the pollution of the ground and destroyed the underground walls; the water was dispersed. After this the "Stabilimento delle Acque della Salute" changed its primary function into: disco; club.
The last use of the building was as a factory. In 1964 Livorno had the major number of bottling factories in Italy. The name of the society was S.T.I.B (Società Tirrena Imbottigliamento Bevande). The factory produced four different drink, the most famous was Coca-Cola.
In the 1967 Coca-Cola society bought S.T.I.B and after three years closed the factory. In the 1967 Coca-Cola society bought S.T.I.B and after three years the factory was closed.

2. THE SURVEY

2.1 Collecting all the available archives and visiting

There graphical maps and detailed information are quite poor about this monument. The main building is not easy to access, but it is possible to visit almost all of the lateral building, because it has been occupied by homeless but also by independent spirits in the past twenty years. Because of a minimal but working maintenance this two parts of the area aren't crumbling like the main monumental area, the work made by people living there was enough to preserve a minimum the conditions of the architectural elements.
The original drawings of the "Terme del Corallo" have disappeared, there are some drawing of sections of the dance hall dome in the civil archives in Livorno. Anyway there is no complete survey of the complex.
But some simple drawing can be a feeble trace but they can be enough to start some planning about a new survey.

Figure 3: The dance hall, the first photo scanning result

2.2 The digital survey

The building is very complex to measure; there are many roofs and vaults near to collapse and so it is very difficult to use direct measurements. Some parts of the building aren't really safe at all: falling windows, falling plaster, the risk of a structural collapse from a vault, a ceiling, a floor.
These are problematic conditions and so it was chosen to survey the building using a medium range solution. Now it is worth stating that there was also the need to operate in a quick, economic and very efficient way, gathering geometrical and images of large and crumbling parts of the building, so a

Figure 4: Section along the dance hall

expeditious photogrammetric solution appeared as a very good choice.
The AGIsoft Photoscan is one of the most recent and well working software for this kind of survey and so it was decided to centre the whole survey campaign on it.
The main needs to produce a good Photo scanning are: a stable tripod and a high definition digital camera. Photos should have a total depth of field; the image should be generated from a lens with an almost “hyperfocal” setting, with all the elements quite clear and readable.
It's important to photograph all the parts of the object; the methods is to divide the object with imaginary section plane, parallels of the surface to photo scanning.
The photographer should move along the imaginary line on the floor (projection of the section plane) with a regular interval with a distance between each position proportionate to the field of view. In each shooting station it is a good idea to take photos from the bottom to the top, paying a certain attention to the floor, while this part should be quite hard to obtain in the final model if not correctly documented. It's necessary to take photos of all interesting particulars to have a detailed Photoscan result.
In this photogrammetric campaign two cameras were used: a Canon Eos 550D 18 megapixels SLR with a basic 18-55mm Canon zoom lens and an Olympus E500 8 megapixels SLR with a superwide angle 9-18mm Zuiko zoom.
To get a good quality in the Photoscan final model it is worth taking more photos than needed, while this might sound unnecessary, when it’s time to create the model some more shots are always useful, a little difference in the point of view, a minimal difference in the quality of similar shots may produce a quite different result.
The further process is the loading of all the images in the software and the start the workflow to create the final digital 3D model of the surveyed space.
This phase can be quite long, because using the software is a time consuming process, starting from a first alignment, to the creation of the geometry to the completion of the process with the creation of the overall texture to be mapped on the mesh surface. The result will be a complete 3D digital model coming from the 2D information of the pictures; the final result is a three-dimensional polygonal surface with a texture applied on it. The texture is created by an union of the photos loaded in the software to start the whole operation.

Because of the possibility to export the model in the most common 3D digital models it is quite easy to bring it in any CAD and rendering environment and develop specific drawings and representations. In this work the main exchange format used were the PDF3D format (for quick view, checking and presentation) and the OBJ format with all the texturing converted into JPG images.

2.3 Integrations and verifications

The post processing of all the photogrammetrically generated 3D models was planned in order to use this survey to recompose and develop a coherent drawings of the main plan, of some meaningful sections and of all the main fronts of the building.
All the information that obtained by photo scanning, became a part of the archives. Some minor direct measurement taken when it was possible and safe, were integrated to complete this task. A simple modelling process, based on the mesh coming from Photoscan was applied to produce the first draft result for developing all the final drawings: slicing the polygonal mesh into orthogonal parts all the base to produce plans and sections were quickly obtained.

Figure 5: Shots for photo scanning from the front on the garden

Bringing high resolution rendering images in Autodesk Autocad it was quite easy to use them as a base to add and integrate the direct measurement. When the drawing wasn’t enough detailed a direct reading of photos taken on each single interesting element was an important step to add details and complete the drawing with the needed quality.

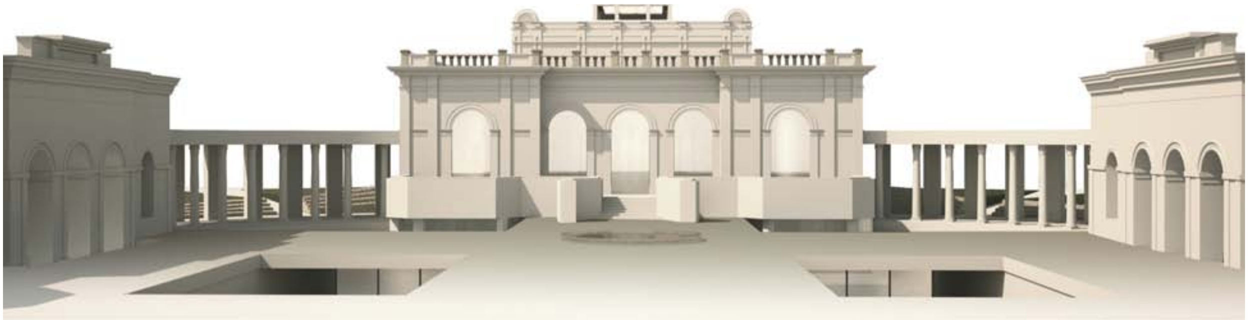

Figure 6: Digital 3D model of the front on the garden

When it was convenient some detail photos were filtered to compensate their perspective and proportioned before their use inside the CAD environment. Little by little a complete and detailed graphical documentation of the monument was completed. With a quite complete plan, main sections and main fronts. A first, useful, set of drawings after years of looking at the monument falling down one piece after the other.

3. THE DREAM OF THE REBIRTH

The idea is a complete restoration of the building bringing it back to its original function of thermal baths and adding to this main role some other important functions like: a café, a modern spa and a large conference hall.

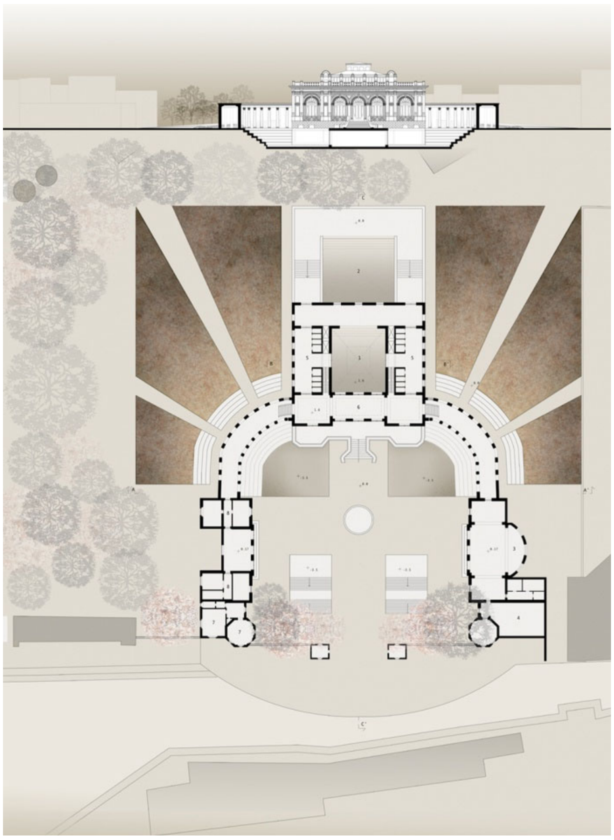

Figure 7: The dream of the rebirth, entrance level.

This choice was inspired by other example of restored thermal bath in Tuscany (Like the “Terme di Montecatini and the “Terme di Salsomaggiore”). In the project the plan recreate the original a “C” shape, it is composed by a central building and other two lateral ones. Inside the main building there is a dome that was built with reinforced concrete; the other two building has the same main front in the direction of the central square; a colonnade connects the three parts.

The building is characterized by a perfect symmetry. This main characteristic suggest a direction and underline also the importance of South-West front. This area was born as an East expansion of the main Livorno town and it doesn’t have very meaningful design rules until the development of the “Terme del Corallo” settlement.

The choice of suggesting a square in front of the main entrance is guided by the will to create a place where it will be possible to appreciate the symmetry of the whole building and also to give an appropriate importance to the main entrance.

The project is aimed at preserving the historical shapes of the thermal settlement and it wants to recover all the historical decorations. For this reason all the new functions are placed underground. In the restoration propose the problem of lighting the underground space is solved excavating below the main colonnade following its same curvature.

The two symmetric excavations, together with the colonnade create a shape similar to the one of an amphitheatre; and the light can penetrate inside this space.

The main function of thermal bath is inside the central building of the complex, the restaurant and café are inside the building on the right side and finally the spa and office are in the left side. The suggested restoration is named “dream of the rebirth” because its will to recreate an almost lost monument, each day put this building even more behind any recovery possibility, but it still has the great fascination of the ruin and the great strength of something created to communicate beauty and welfare. So this is the focal point, the water, the place, the will of beauty and the mood of the place must recall the identity of the area, a certain spirit of the town, enhancing the sense of awesome spatial elements in front of the poor speculative housing developed all around the “Terme del Corallo”.

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3.1 Acknowledgements and Appendix

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AN INTEGRATED METHODOLOGY FOR THE DIGITIZATION, SURVEY AND VISUALIZATION OF SANTA MARIA PATIRION'S CHURCH

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KEY WORDS: Laser scanning; 3D modeling; Cultural Heritage; Immersive visualization.

ABSTRACT:

In this paper we present a methodology for the digitization, the survey and the visualization of a 3D model built from a large scale object that combines the use of different hardware, software and geometric data. The results are a detailed virtual model used for the documentation of the preservation status of the artifact and a simplified 3D model for the navigation with an immersive stereoscopic visualization system.

1. INTRODUCTION

The demand for 3D digital models of historical monuments in the field of archaeological and architectural applications is currently growing (Salonia, 2009), and digital systems and environments are more and more used as a tool for preservation, reconstruction, documentation, research and promotion (Bruno, 2010). Photorealistic 3D models may be developed for very small objects or whole buildings. These models are generally developed by means of 3D scanning techniques, in order to acquire the objects in a faithful way (Fowles, 2003, Boulanger, 1988, Akca, 2006, Tsioukas, 2004). Generally, when the digital documentation is focused on monuments, buildings or entire sites, 3D models are created with terrestrial laser scanners, thanks to their high acquisition speed and precision. This process allows to obtain geometric models of great accuracy (Lichti, 2004), (Ergun, 2010). Recently, the availability of increasingly powerful hardware and software has brought to the spread of photographic techniques that allow to create models with an acceptable accuracy and reduced costs (Shashi, 2007). Even if these technologies provide a detailed description of the geometry, on the other hand the data post-processing necessary to produce a lightweight but realistic model is often prohibitive for the huge amount of data. Therefore, the development of Virtual Reality applications dedicated to the fruition of Cultural Heritage still remains a complex task, especially if these techniques have to be applied to buildings or complex sites.
In this paper we describe the methodology that has been used for the survey, the analysis and the 3D reconstruction of the Patirion Church (Rossano – Italy). After drawing a brief historical frame, the paper describes the acquisition procedure and the subsequent geometrical analysis. For the survey we employed a Leica HDS3000 Time-of-Flight laser scanner and a Leica TCR 407p total station. Views and sections derived from the point cloud were used to conduct a thorough diagnostic study of the building. Finally, the paper presents a contribution to overcome the above mentioned problems, by suggesting some guidelines for the post-processing of very dense point clouds, in order to produce a 3D model completed with high resolution textures mapped from a set of photos. The virtual model was then made accessible through an interactive application implemented using Virtools™, that allows a real-time navigation in the entire building.

2. THE CASE STUDY

The St. Maria Nuova Odigitria's Church (called Patirion) is located 605 meters above sea level, on a branch of the Sila mountains facing the Ionian Sea between Rossano and Corigliano, in the province of Cosenza (Calabria, Italy). The church (Figure 1), which is part of a larger architectural complex that includes also some small remains of an ancient monastery, is the result and the emblem of the successful fusion of three civilizations, Byzantine, Arab and Norman.
The church, built in stone, features a 3-aisled basilica plan, a sober façade dominated by a central rose window and three Byzantine domes. The part of the church in better condition is the exterior one, composed by three apses decorated with the typical Norman architectural elements.
The floor of the church is the part that enriches the most the entire complex: in front of the main entrance there is a large mosaic. For further information relating to the mentioned site please see (Orsi, 1929).

3. PHASES AND TOOLS OF METHODOLOGY

The following paragraphs provide a detailed description of the different phases of the process (Table 1). It has to be noted that the data reported starting from the modeling phase are related only to the exterior of the church. The interior part is currently under processing, therefore no quantitative data are available.

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3.1 3D Data Capture of the Church

For the survey we adopted an approach which consists in the integration of the data obtained by the time-of-flight laser scanner Leica HDS3000 and the total station Leica TCR 407p.

Figure 1: St. Maria Nuova Odigitria's Church (Patirion)

The laser scanner employed can operate in a wide field of view (360° H x 270° V), and is able to generate a cloud of 1800 points per second with an accuracy of ±2mm on the range of 1÷50m. The total station has an angular accuracy of 7” and a range of the laser beam of 200 m.

The process requires the arrangement of the targets to be acquired both with the laser scanner and the total station to facilitate the positioning and alignment of the scans. The notable dimensions of the building led to a division of the work in different daily phases. We have developed an open polygonal curve with control points, having as vertices the points of the station and as points of interest the targets and several easily identifiable references in place. The entire complex has been covered with a polygonal of 10 station points, while for the acquisition of the point cloud of the outer surface of the church, 10 Scanworlds (single positioning of the laser) were required (Figure 2).

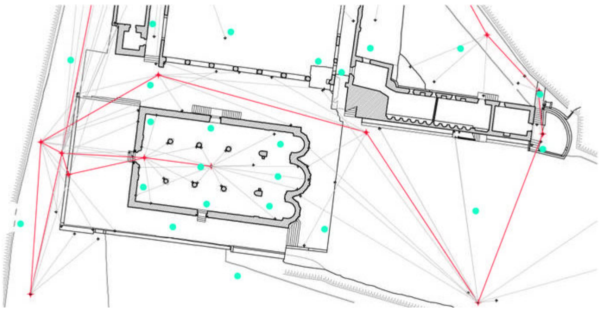

Figure 2: Positioning of Scanworlds (blue) and station points (red) for the internal and external acquisitions.

Phases	Activities	Hardware	Software	Data
3D Data Capture	Integration of data related to the scans of TOF laser scanners and total station.	TOF Laser Scanner Leica HDS3000; Total station Leica TCR 407p.	Cyclone (Leica)	Point cloud (87 millions)
Data Analysis	Extraction of technical drawings for a diagnostic documentation of the preservation state	Workstation with Intel ® Core ™ i7-2600 CPU @ 3.40 GHz, 8 GB Ram and 64 bit operative system. Digital cameras	CloudWorx (Leica)	10 Technical drawings
3D Modelling	Refining and decimation of point cloud and creation of the triangulated model.		Bundler - PMVS2	3D model from photos
			Meshlab	Triangulated model
Texturing	Perspective correction, crop and equalization of photos. 3D Mapping of the photos on model	Digital Cameras (Nikon D90, D200 and D5000)	Gimp Bundler	200 images
Fruition	Development of an application for the exploration and the navigation of the 3D model in a virtual environment	Workstation with 50” 3D TV monitor- full HD	Virtools (Dassaults)	3D model with 1,000,000 polygons

Table 1: Phases, tools and data of our methodology

The interior of the church has been acquired with 8 Scanworlds at higher resolution, in order to avoid acquisitions with an angle of the laser beam smaller than 30. To check the proper alignment of the point clouds of the interior, we have also run an overall Scanworld for the whole interior. The Scanworlds have been aligned by means of a series of targets and subsequently processed with the Cyclone software, reaching a maximum alignment error of 6 mm.
In order to create the texture of both the interior and exterior, more than 500 images were acquired using different high-resolution cameras.

3.2 Data analysis

For the restitution of the canonical drawings (plans, elevations and sections) we followed a procedure that allows to obtain flat sections directly from the point cloud while working in a CAD environment, using the CloudWorx software: in this work environment, reference systems and planes were created and saved in the database.
The management of the large amount of information obtained from the scan has been simplified, as it is possible to extract only the band of points needed to generate the section. With this method, by proceeding through different planes along the point cloud, we obtain the various plans, elevations and sections (Figure 3).
The diagnostic element is extracted and analyzed from the information provided by the geometric model. In particular, we found a series of evidences during the examination of the extracted surveys:

- a flaw of horizontality of the crowning cornice of the central apse of 23 cm;
- the central apse has a failure towards South of about 11 cm;
- the left side of the central apse has an out-of-plumb towards the outside of about 10 cm;
- the masonry present above the central apse has a concavity of about 22 cm;
- the shelves that support the cornice are poorly finished and differ from each other;
- the slope of the floor is turned towards the apses, featuring a difference in height between the two ends of the nave of 31 cm;
- the axes of the North and South portals differ from each other by 15 cm;
- the perimeter openings present at the average height of +6.70 m are not aligned with the arcades and are located at variable height, with some asymmetric splays as well;
- no opening is aligned with those below;

furthermore, from an examination of the side survey, we note that the building has a gradual drawdown with respect to the ground level, if referring to the constructive height of the rear façade.

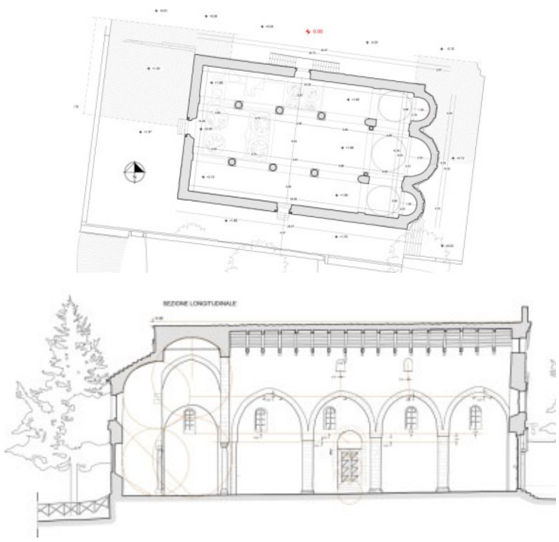

Figure 3: Some geometrical drawings useful for the diagnostic documentation of the preservation status.

3.3 3D modelling

For the registration of multiple scans in a single reference system, the positions measured with the total station have been used. The result is a single point cloud of about 87 million points, that integrates internal and external scans of the Church. In order to be post-processed, it has been exported from Cyclone.
The obtained model results to be unmanageable: any operation on the cloud turns out to be very slow, thus preventing any real-time interaction. The first step was the differentiation of the scans belonging to the interior and the exterior of the building in two files, thus obtaining two clouds of about 31 million points and 56 million points, respectively (Figure 4).

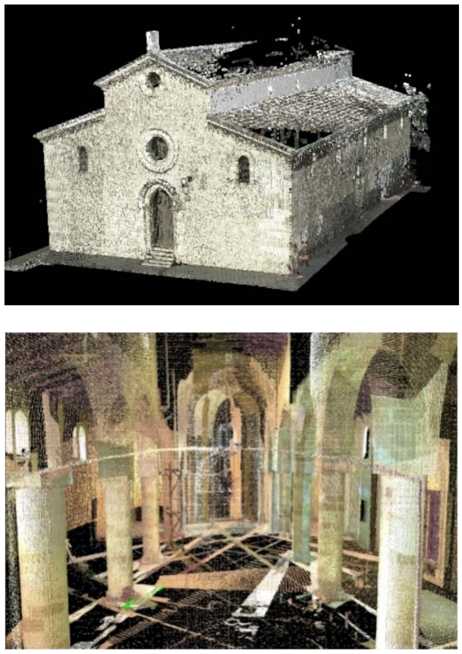

Figure 4: (a) external cloud with 56 million points; (b) internal cloud with 31 million points.

Both models have very dense areas and also areas with few points because there are some parts not optically accessible from the scanning positions. At present, we focused on the 3D modeling of the exterior of the church. So, hereinafter, we will refer exclusively to the reconstruction process of the exterior.
The open source mesh processing software MeshLab has been employed for a first filtering of the noise due to the acquisition. After an additional sub-sampling filter useful to reduce the amount of data without losing quality, the initial point cloud of 56 million points has been reduced to 10 million points. Subsequently by means of the Poisson Surface Reconstruction Algorithm included in Meshlab, we obtained a triangulated mesh of about 20 million polygons.

3.4 3D model refinement

The surface reconstructed from the data acquired with the laser scanner is affected by noise due to surface properties and lighting condition and some missed areas due to occlusions. Furthermore, some elements have been modified after the restoration intervention, such as the stairs on the left side of the church (Figure 5 a). Thus we have decided to integrate the model reconstructed with the laser scanner, with a surface reconstructed by using a multi-view stereo technique (Seitz, 2006) on the sequence of images taken for texturing purpose. In particular the SFM (Structure from Motion) software Bundler (Snavely, 2007) has been used to compute the camera position in 3D space. Then, the multi-view software PMVS2 (Furukawa, 2007) has been used to create a model of about 8 million points and 15 million polygons. (Fig 5 b). The model has been computed up to an unknown scale factor, so it is necessary to scale the 3D point cloud obtained only by pictures by using a reference know distance.
The next step involves the alignment of the new 3D data to the one obtained with the laser scanner, by using the ICP (Iterative Closest Point) algorithm. Finally, the cleaning and mesh editing tool provided with Meshlab, has been used to fill the holes and remove all the surface defects on the merged model (Fig 5 c). The final model consist in about 30 million polygons, decimated to 1 million in order to produce a model navigable in real time maintaining a good accuracy.

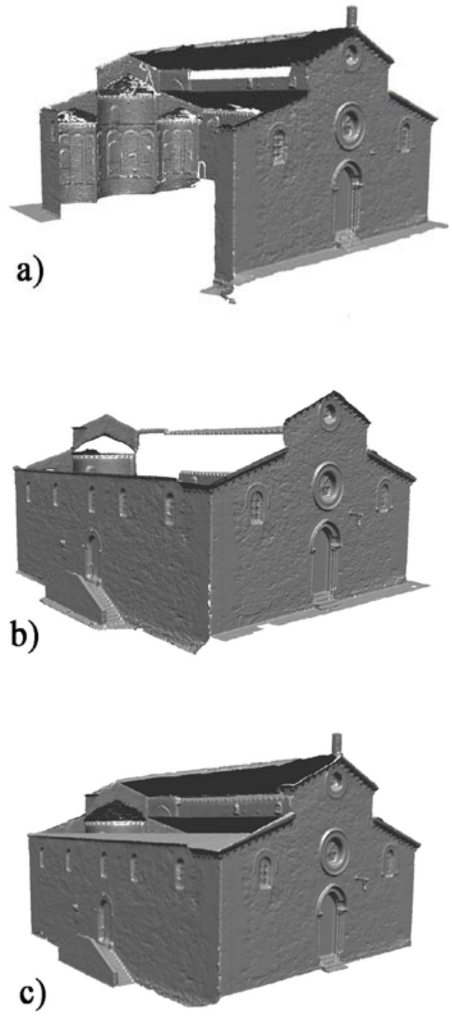

Figure 5: Laser scanner model (a), 3D reconstruction by multi-view stereo (b), merged model (c).

3.5 Texturing

Each scanner has its proper camera to acquire RGB images, but with a quality that was too poor to be used for a photorealistic model. For this reason it was necessary to use a high-definition digital camera to reconstruct all the details in a reliable way. Some procedures of colour, exposure, lighting and contrast correction were done, on about 200 pictures that have been taken for the exterior part of the church. The texture-mapping procedure is based on a photogrammetric process, that performs image orientation automatically without using calibrated cameras or control points such in (Valanis, 2010).
In particular the SFM software Bundler is used to compute the camera positions ad a sparse reconstruction of the scene, that have been scaled and aligned with the refined model (fig 6 a). Since the camera position are known, it is possible to map the images on the refined mesh by projection mapping (Figure 6 b), adopting a weighted average in order to avoid artefacts on the resulting texture due to changes in lighting and point of view. With this approach will not be necessary to find manually control points on both images and 3D model such in (Stathopoulou, 2010). Figure 7 shows the final refined model mapped with the high quality texture.

3.6 Fruition of the Virtual Model

The textured 3D model has been exported in VRML format to keep the texture mapping within the visualization environment.
This format allows us to manage a repository with highly detailed data that can be made available to the public.
The software application was developed using the Virtools package and run on workstation connected to a 50” full HD active stereo monitor (Figure 8). The user interface consists of a trackball and four buttons. The user can choose between a manual and an automatic first-person navigation system. In manual navigation, the user can decide the direction where to move, by translating and rotating the virtual camera; the system uses the uses the Collision Detection to prevent the penetration into the surfaces. The automatic navigation, however, makes the camera follow a predefined path curve in a loop until the user decides to return to manual navigation.

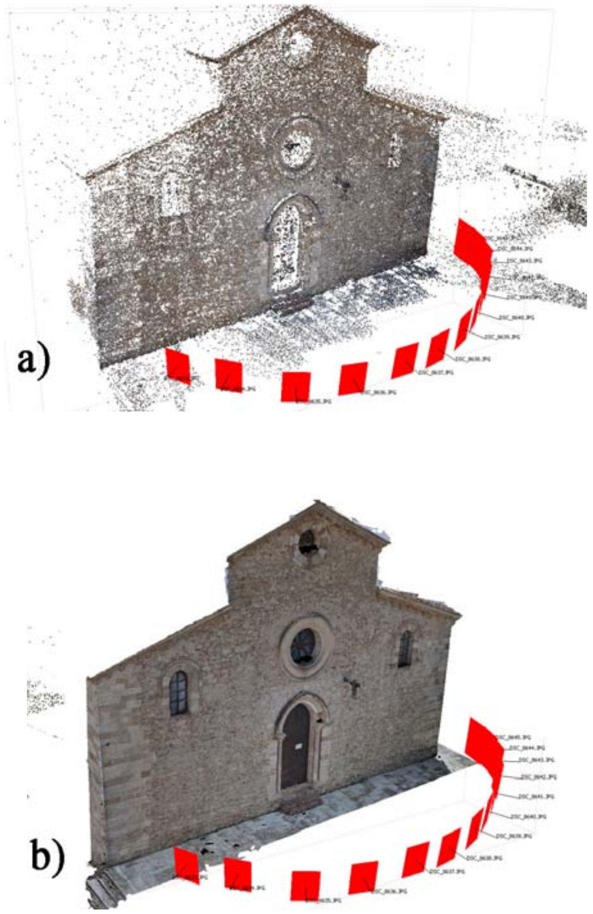

Figure 6: Texture creation. Multi-view reconstruction of the church façade (a) and camera station oriented on the model created with the laser scanner (b). The red squares represent the camera positions.

4. CONCLUSIONS

In this work we proposed an integrated method for the creation of accurate and interactive 3D models with a high level of detail but easily manageable. The goal was to obtain virtual models that could be analysed both for the generation of technical documentation and the real time visualization on virtual reality systems.
The described methodology was applied to the reconstruction of the church of St. Maria Nuova Odigitria, located in Rossano (Southern Italy). The obtained results fulfill both the defined goals, but only after a very onerous data post-processing.
For the preparation of the documentation concerning the preservation status of the artefact, it was necessary to carry on a scan campaign that required many days of work and a long and complex processing of the technical drawings**.**
The data processing work required to make the model navigable and interactive in a virtual environment was even more onerous. The main difficulty lies in finding the right balance between texture resolution and number of triangles, i.e. to maintain a good balance between the manageability of the model in real time and the accuracy of the reconstruction. The obtained results show a good integration of details and architectural features in the overview of the structure on a large scale. Currently, the 3D reconstruction refers to the outside of the church and so we have not yet published our data on the web (i.e. www.europeana.eu).

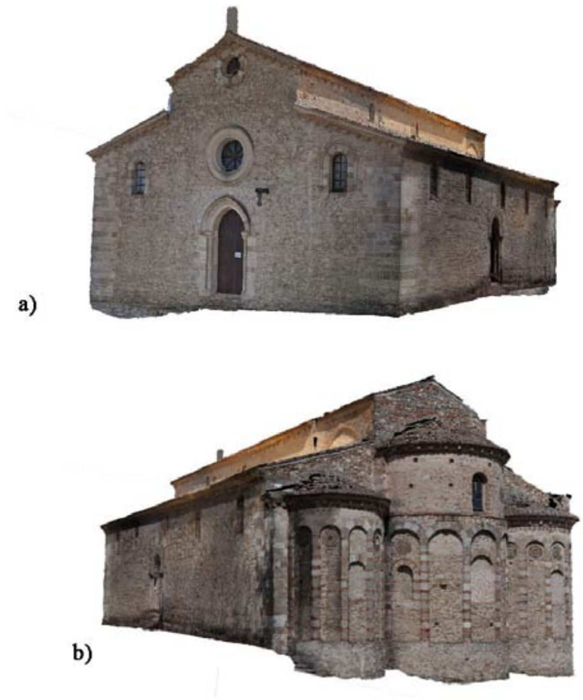

Figure 7: Texture mapped on the final model.

Figure 8: System for the fruition.

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DOCUMENTING A UNESCO WH SITE IN CYPRUS WITH COMPLEMENTARY TECHNIQUES

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CIPA, ICOMOS and WG V/2: Advances in Digital Documentation

KEY WORDS: Cultural Heritage, Photogrammetry, TLS, Orthoimage, Rendering

ABSTRACT:

According to UNESCO directives, the documentation of monuments is a complex task, which both terrestrial laser scanning (TLS) and photogrammetry can decisively support. Today, these techniques are considered complementary, as they demonstrate clear advantages and disadvantages to each other, with regard to representation, texture application, data gathering, acquisition and processing time, practicality, accuracy, data density, surface reflectivity and absorption. In an effort to clarify which part should be acquired with which technique, as well as to understand whether one technique has a clear advantage over the other in some specific task of the documentation process, the Church of the Holy Cross in Pelendri, Cyprus, which is a UNESCO World Heritage monument, was selected as a test site. The deliverables are orthophotos, sections, plots and a complete and accurate 3D model of the monument. The whole documentation process has been carried out independently using an image based technique with Menci's ZScan and terrestrial laser scanning Leica's ScanStation 2, supported by high resolution digital images. Data acquisition has been carried out in parallel while the final products have been created independently by each one. It is clear that the processing phase of photogrammetry is more time consuming than the equivalent in TLS, but high quality texturing and the orthophoto production process are included within the processing, hence image based techniques present an advantage. As for their final accuracy, both techniques deliver satisfactory results within the required scale tolerances. Their individual merits are also presented, discussed and evaluated in this paper.

1. INTRODUCTION

One of the three UNESCO WH sites in Cyprus is the group of the ten painted Byzantine Churches in the Mount Troodos

Figure 1: The WH site on Mount Troodos in Cyprus

(Figure 1). They date from the 11th c. AD and are famous worldwide for their architecture and frescoes. The Laboratory of Photogrammetry in cooperation with HTI initially and CUT, Dept. of Electrical Eng. and Information Technology nowadays and with the help of the Church of Cyprus and the Department of Antiquities of Cyprus has undertaken an effort for their documentation and three dimensional visualization, with contemporary techniques (Sophocleous et al. 2006, Agapiou et al. 2008a and 2008b, Chrysostomou et al. 2008, Georgopoulos et al. 2009, Agapiou et al. 2010).

The geometric documentation of a monument 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 given moment in time (UNESCO 1972). The geometric documentation records the present of the monuments, as this has been shaped in the course of time and is the necessary background for the studies of their past, as well as the plans for their future and e-preservation.

Technological advances in recent years have spectacularly multiplied the variety of sources for collecting metric information at such large scales. In order to fully exploit these data, special techniques should be developed. Moreover, the advancements in computer industry have enabled the three dimensional visualizations of the monuments in a virtual world. The compilation of 3D models of historical monuments is considerably facilitated by the use of dense point clouds, which are created by terrestrial laser scanners. Their combined use with photogrammetric procedures, such as the production of orthophotos, allows the realistic 3D representation of complex monuments such as sculptures. In this context virtual reality tours have been created for simple or more complex monuments (Georgopoulos & Ioannidis, 2007). This ability has greatly contributed to the thorough study of the monuments, as well as to the creation of virtual visits. At the same time, the plethora of methods proposed by the manufacturers offers a multitude of alternatives to the potential user. The purpose of this paper is to investigate the possibilities and limitations of two different approaches to the geometric documentation of the Church of the Holy Cross in Pelendri Cyprus.

2. DESCRIPTION OF THE SITE

2.1 History of the Church of the Holy Cross

The Byzantine church of the Holy Cross is located in the village of Pelendri in the region of the Mount Troodos in Cyprus. Inside the monument the wall paintings are of such great artistic value that the church has been included on the World Heritage List of UNESCO together with 9 others of the same region. The current form of the monument is the result of many additions and alterations upon the initial construction phase. The Church of the Holy Cross is a basilica with a dome (Figure 2).

Figure 2: The Church of the Holy Cross in Pelendri

The monument appears to have been built in the 1178 A.D, according to an inscription on the apse of the sanctuary. The original church was single aisled with a dome in the centre and arched recesses in the side walls. In the early 14th century the church was destroyed by an unknown cause. During the rebuilding of the church at that time and probably in the same reconstructive project, two aisles were added one to the north and one to the south.

The existence of old wall paintings was revealed under the 14th century layer of plaster in the main apse, during maintenance works of the church in the early 70's. Following the discovery of these frescoes of the 12th c. during the cleaning and maintenance of the decoration of the church by the Department of Antiquities of Cyprus, those of the second layer were detached and placed onto an additional drywall at the corresponding point of the south aisle, where they have been up to the present day. The frescoes have serious damages because of the decorative plastering in the 14th century (Hadjichristodoulou 2005, Zarras 2010).

3. METHODOLOGY

For the geometric documentation and 3D visualization of the Church of the Holy Cross, two different approaches were employed. Firstly, the "classical" contemporary methodology involving laser scanning and high resolution digital imagery for producing the 2D imagery products, i.e. orthophotos, and for texturing of the 3D model. On the other hand the ZScan system by Menci was employed. As it will be described later, it is a purely image based hardware and software combination for producing 2D and 3D geometric documentation products.

3.1 Description of survey network

All data acquisition actions should be referenced to a common coordinate system, in order to enable the necessary interrelations. A survey network is essential for this purpose. Two interconnected traverses were established, one outside (E1-E6) and one inside (m1-m6) the church (Figure 3) in such a way to allow measurements to all parts of the monument.

Using contemporary total stations (Topcon GPT 7003i and Leica TPS 1200) the measurements of the network resulted to an adjustment accuracy of less than 10mm. The survey stations were discretely marked with small paper targets.

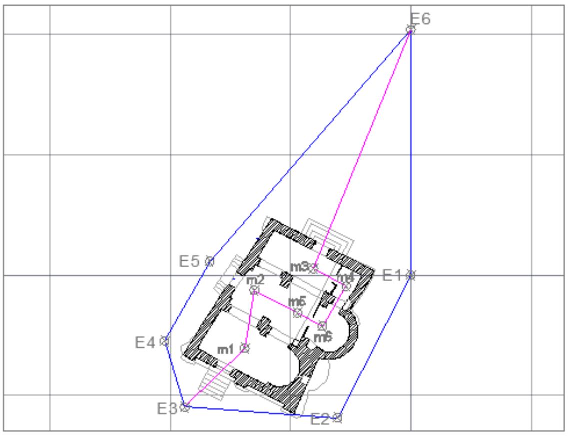

Figure 3: The network established outside and inside the Church of the Holy Cross

3.2 Data acquisition

3.2.1 TLS and Digital Imagery: Data acquisition was carried out using terrestrial laser scanning and classical photogrammetric methods. A Leica ScanStation 2 ToF laser scanner was used to collect the point clouds of 1cm density from the outside and the inside of the church. At least three targets common to each pair of scans were positioned either on the walls or on tripods for aligning the point clouds later. A Canon EOS MIII full frame 21MP DSLR with a 24mm and a 50mm calibrated lenses was used for acquiring the digital images. Effort was made to take these images as frontal as possible, especially in the interior, in order to render the 3D model and produce the orthophotos as reliably as possible.

Either pre-marked points or detail points were used as GCP's. All GCP's and scanner targets were measured with the total stations and referred to the common coordinate system. This would help the point cloud registration and ensure maximum accuracy.

Laser scanning for the exterior and the interior of the church lasted 22 hours and 185 million points were collected. Of those 22 million were for the exterior point clouds and 163 million for interior ones. This is due to the complexity of the interior of the monument. The laser scanner was placed in 12 different positions, 5 inside and 7 outside. For taking the images, 13 hours were approximately necessary, as the use of artificial lighting was imperative for the interior takings. 174 images were taken in total, 129 in the interior and the 45 in the exterior of the monument. The total capacity of these digital data is approximately 13.5GB, of which 3.3GB occupy the laser scanner databases and 10.2 the digital images.

3.2.2 ZScan. ZScan is a system of 3D colored point cloud generation, through automated processing of digital images, which have been taken with a special system of stereoscopic triplets. The ZScan kit is composed by a DSLR camera (Nikon D90) with a fixed 24mm lens, a slide bar of 900 (Figure 4) or 1600 mm length, on which the camera is sliding and is positioned in fixed points on the bar and, of course the ZScan software (http://www.menci.com/zscan/index.php?option=com_content&task=view&id=10&Itemid=28).

Figure 4: The typical setup of the ZScan and the slide bar

Image acquisition with ZScan is more or less similar to the classical terrestrial photogrammetric one, the only difference being that the user acquires triplets of images from the fixed positions on the slide bar. The factor that differentiates these two methods is the restriction of distance. With the ZScan system the operation range varies according to the length of the slide bar which will be used; from few centimeters, with the micro ZScan bar, up to 6 m, with the slide bar of 900 mm length, or even 10 meters, with the slide bar of 1600 mm length. In order to avoid measuring a lot of GCP's, it is recommended that neighboring triplets should have model overlap greater than 20%. When GCP's were measured, they were either pre-marked or detail points. The base varied from 500 mm to 900 mm, depending on the camera to object distance. Some of the external imagery has been taken with the 1600mm base with three synchronized Nikon D90 cameras. During photography, it is essential to record the base that each triplet is being recorded so that to import it in the software during processing.

Experience with the ZScan has shown that the closer the object of interest was situated, the more triplets were needed to cover it adequately, as it was the case in the interior with the confined space. On the other hand, for outside work, the longer slide bar was used. In total 211 triplets were acquired during three full days of field work and 9.5GB of disk space.

3.2.3 Horizontal and vertical sections. For the complete geometric documentation of the church one horizontal and six vertical sections were also determined, to serve as framework for the orthophotos (Figure 5).

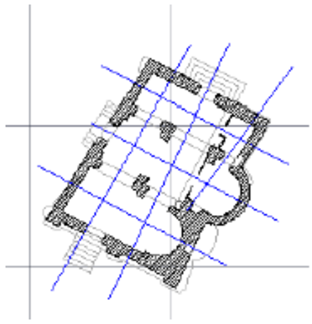

Figure 5: The footprints of the six vertical sections

The characteristic points of the sections were measured using a total station. For the interior the sections were measured using the TheolT software (http://www.theolt.com/web/) in combination with the Leica TPS 1200 total station and AutoCAD. This software actually intervenes between the total station and the CAD software by converting in real time the surveying measurements to coordinates while at the same time making available all CAD commands. The drawing is constructed in real time and in 3D (Figure 6).

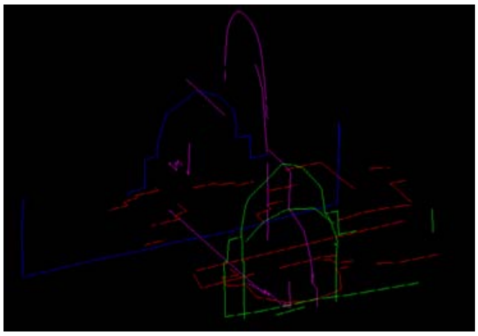

Figure 6: TheoLT real time 3D drawing

4. DATA PROCESSING

4.1 TLS and Digital images

The data processing stage includes processing of the survey measurements, aligning of the point clouds collected by the laser scanner and georeferencing them into the local reference system, as well as their conversion into surfaces. Calculating from point clouds the corresponding surfaces is a necessary process for the creation of the 3D model, which will be used for the stage of orthoimage production, but also for the rendering of the Digital Surface Model. The digital images taken were oriented using standard photogrammetric methods both for the creation of orthoimages, but also for texture mapping of the Digital Surface Model.

Data processing of the laser scanner point clouds was performed using Cyclone software which accompanies all Leica Laser Scanners. The interior and exterior point clouds were processed separately for better management of the information and because of the large amount of data. During the pre-processing phase all scans were cleaned from unnecessary noise, i.e. points belonging to objects not belonging to the monument itself, e.g. passing people, chairs, tables and other heavy things. Using the special retroreflective targets, the scans were registered in an arbitrary system. The maximum error at a target between two successive scans in the interior of the church was 4mm and in the exterior 9mm. Both results were satisfactory and within the scale tolerances. After that, the measured dataset of the targets was imported to the software, as a new scan. The previously registered scans were then registered to this new one and thus referenced to the local coordinate system. This process was performed with accuracies of less than 12mm.

The next step was the mathematical creation of accurate surfaces from the set of the registered point clouds in order to create the 3D model of the church. The data processing of the point clouds was done using the Geomagic Studio® v.10 software. Once again, there was a separate process for the internal and external part of the church for the same reasons as before. The software provides a variety of automatic algorithms for point and triangle reduction. For the exterior, the points were reduced to 18 from 22 million and the triangles of the surface from 9 M to 0.8 M without significant loss of reliability. For the interior the decimation process reduced the points from 163 M to 2 M and the triangles to 0.8 M again. During the meshing phases, holes in the final models caused by lack of information or noisy data were filled with the automatic hole filling tool. At the end of this process the two models were ready to be textured, and also to be used as Digital Surface Model at the stage of orthoimage production.

The next step was the orientation of the images that were taken and depicting the monument. This action was performed using Topcon's Image Master® software. A standard bundle adjustment algorithm is implemented by the software. The accuracies were well within the scale tolerances, i.e. less than 15mm in X, Y and Z both for the exterior and the interior images.

Orthoimage production followed using the oriented images and the Digital Surface Models imported into the Image Master® software in .dxf format. The final orthoimages were radiometrically corrected using standard image processing software for best optical results. Texture mapping of the models was also performed at this stage, while the model was divided in parts. Using a particular part of the model and the image that was best imaging it, rendering of the 3D model was done, while choosing the right rotation angles each time. When a texture map is created, at the program, the result is a rendered image of the textured model from a selected view and not a developed image of the textured surface of the model. This means that areas that are not visible in a view are poorly mapped (Valanis, Tapinaki, Georgopoulos, Ioannidis, 2009).

Figure 7: Results of the TLS and photogrammetric processing, orthoimage (left) and 3D rendered model (right)

Figure 8: Orthophotomosaic of the western façade

4.2 Zscan Triplets

As already mentioned, Menci's Zscan is a medium to high cost trifocal photogrammetric system. It might be used with a single camera or three similar cameras synchronized for triggering. Cameras are calibrated by the company and can be positioned on a rigid bar mounted on a tripod. ZScan actually employs all Digital Photogrammetry principles, producing 3D point clouds via dense image matching procedures. However, photogrammetric processing in ZScan workflow differs from the standard one in the sense that the processing must be done in image triplets.

Triplets of images with a priori knowledge of relative positions are acquired, thus the 3D reconstruction of the scene is achieved via multi image matching software with a user friendly interface, but with no possibility for the user to intervene. The major advantage of the system is the ability to measure objects without any control, since the scale is obtained through the rigid bar and the known base. Relative orientation in being performed for every given triplet, since the positioning differs slightly each time the camera is positioned on the bar. If control points are available, they can be used for exterior orientation of the triplet provided that they can be measured in all images of the triplet. Additionally, if triplets have 20% overlap, the user can select "bundle" adjustment, which is an independent model adjustment.

The processing of the imagery up to surface creation is user friendly and straight forward with minimum options for the user. Image files are downloaded in the computer and with a semi automated way imported as triplets. For each triplet the base distance need to be typed. A list of coordinates is being used to import control points and the control points are manually measured in at least one image of each triplet. The software is using epipolar constrained image matching to locate the control in the rest images of the triplet and the user can correct it if necessary. After this initial process the user selects a number of triplets that he wishes to orient and runs bundle adjustment. Adjustment either finishes successfully or not, without any additional measure of correctness. Following that, all triplets are being processed for 3D point extraction and surface creation.

Both bundle adjustment and image matching are time consuming processes, the latter depending heavily on user options. The final product can be exported as color point cloud, or further processed using ZMap for orthophoto creation. ZMap allows the user to select appropriate projection plane and provides tools for 2.5D processing of the DEM prior to orthophoto creation.

4.3 Products

It was decided at the beginning that using both methodologies similar products would be produced, i.e. orthophotomosaics and a rendered 3D model, which would possibly lead to a video of virtual visualization. Consequently a number of drawings have been produced, most of them using both methodologies. These drawings, which include orthoimages fully document geometrically the monument. However, there are some problems, especially as far as the dome is concerned, because there was no possibility of hoisting the instrumentation at a suitable height. The surrounding area was not accessible by a vehicle. Some samples of these products are presented in Figures 8 & 9.

Figure 9: Vertical cross section facing east

In addition, the 3D model was constructed using the point clouds from the terrestrial laser scanner, as they were more complete. It was rendered using the Image Master® software and saved as a 3D Acrobat Reader® file (Figure 10).

Figure 10: The 3D model of the interior of the church

5. COMPARISON OF METHODOLOGIES

Undoubtedly Zscan hardware is lighter, easier to transport and setup and all in all more operational than the particular terrestrial laser scanner. There are, however, terrestrial laser scanners already in the market, which are not of that size. The laser scanner is heavy and huge comparing to ZScan, as well as approximately four to five times more expensive. Moreover Zscan appears to be more effective in areas where access is limited. Moreover the transportation and the installation of the laptop accompanying the laser scanner were rather time consuming actions and often distracting.

Data acquisition differs a lot between the two techniques. TLS was faster in the inside, where the Zscan system, due to the confined space and despite of the use of 24mm lens had to compensate with many photo triplets for full coverage. Outside of the church, the situation is reversed. In any case the TLS process had to be followed with an image acquisition session for texturing, which slowed down the overall process.

The total time of raw data collection in the case of ZScan was 55% less than that of the laser scanner. On the other hand laser scanner produces the 3D point cloud in real time, contrary to Zscan, which needs a time consuming procedure in order to create a point cloud. Nevertheless, ZScan creates a 3D point cloud complete with texturing information, while laser scanner does not. A complete time comparison is presented in Table 1.

Undoubtedly, as it was mentioned before, laser scanner predominates in controlling the acquired data in situ, as the user can examine the point cloud in real time. Therefore, human error factor reduces in this case, in contrast to ZScan, where the user is very likely to miss out part of the object. Moreover, in the case of the laser scanner the cloud density is determined at the time of data acquisition and can only be decreased later.

As far as range is concerned, it is one of ZScan's biggest disadvantages since it does not allow the user to capture surfaces which are more than 10m away even with the longer available slide bar. In contrast, the range of this specific type of laser scanner (ToF) reaches 200m.

The volume of data collection is huge in the case of the laser scanner, because mainly the increased density applied in the case of the dome interior. The files which are generated were difficult to manage and data ought to be processed separately, which would be done anyway. On the other hand, the size and the organization of files in the case of the ZScan are quite easier provided that care has been taken during fieldwork to note down all particular details. Furthermore, the number of the control points necessary to georeference the triplets was less in the case of the Zscan compared to the total number of GCP's necessary for the orientation of the digital images. On the other hand, 13 scans were necessary to cover the inside and outside of the monument with the laser scanner, while with the Zscan 95 different setups were needed. This leads to more tedious fieldwork and to eventual errors in point cloud registrations later.

	Z-scan	TLS+DSLR
Survey Measurements (common)	110	110
Fieldwork	27	35
3D point cloud	500	440
Orthoimages	300	360
Radiometric corrections	80	35
Texture mapping	-	33
Final drawings (common)	120	120
Total time (hrs)	1137	1133

Table 1: Comparison of methodologies (hours)

The production of orthoimages in the ZMap software is much quicker than with the conventional method. It should, however, be noted that the possibility for corrections to the Digital Surface Models is limited in the case of Zscan. Its main advantage is the unified manipulation of the surface and the imagery, which provides high quality 3D photorealistic models and excellent orthophotos. Since calibrated cameras are being used, there is no remaining effect of radial distortion that cannot be modeled with DLT (in comparison with laser data and external camera). On the other hand its use in confined spaces is awkward, as the number of triplets is increased rapidly.

As far as total time and consequently total cost are concerned, the two methodologies have been evaluated with the survey of the specific monument in mind. Surveying measurements were common, as the basic coordinate reference system should be common in order for the results and their comparison to be objective. In Table 1 the results of the time statistics for both methods are presented. Finally, it should be noted that both techniques make use of costly equipment and software. If cost estimation was attempted, the ZScan method would prove only by 5% cheaper.

6. CONCLUDING REMARKS

The geometric documentation of monuments is a challenging and complex task and both techniques managed to support it adequately. They proved to be complementary to each other as no method appears to have a clear advantage over the other. Of the two methods ZScan has the advantage of being an automated method that does not require the user of having a photogrammetric knowledge whereas the disadvantage is the incompatibility with other software. Both techniques as for their final accuracy deliver satisfactory results within the scale tolerances. Each technique has merits in different fields, e.g. if a low density model is required, Zscan is ideal as it may provide it very fast and does not require special knowledge from the user.

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VISITOR MOVEMENT AND TRACKING TECHNIQUES. A VISITOR-SOURCED METHODOLOGY FOR THE INTERPRETATION OF ARCHAEOLOGICAL SITES

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KEY WORDS: Archaeological Walks, Visitor-sourced Data, GPS-tracking, Geo-tagging, Density analysis, HotSpot analysis, Gournia

ABSTRACT:

This paper describes on-going research investigating movement and behaviour patterns of visitors in archaeological sites as a way of informing interpretive planning. A critical point of this study was the development of a hybrid methodology for collecting and assessing data on visitor movement around archaeological sites and of the things that visitors value the most during their visit. This paper demonstrates the methodology developed mainly at Gournia, a Minoan archaeological site of eastern Crete in Greece. Apart from recognised forms of observation and the collection of qualitative data, technologies such as Geographical Positioning System body tracking, geo-tagging and applications of Geographical Information Systems were employed. The interpretation of the processed data provided a better insight and an overview of the site's affordances for movement and as well as the weaknesses of the current interpretation infrastructure. Additionally, the methodology extends to a visitor-sourced approach to reveal the site's 'hot spots' by combining hotspot analysis with a thematic analysis of the geo-tagged images captured by visitors.

1. INTRODUCTION

1.1 Establishing a visitor observation methodology for archaeological sites

Considering that heritage is ‘inherently a spatial phenomenon’ (Graham et al. 2000: 4), heritage interpretation occurs at certain spaces whether at a museum, a historic urban centre or an archaeological site. The importance of observing visitors’ interaction with cultural heritage spaces and exhibits was early on acknowledged in museum studies as a valid methodological tool used to inform and assess interpretive design (Bitgood & Patterson 1986a, Bitgood & Patterson 1986b, Bitgood, Patterson, & Benefield 1988, Klein 1993). So far, a variety of methodologies have been developed and employed to understand the visitor perception in the museum context. In parallel to this, considerable theoretical work exists on ‘the visitor perception’ in the context of cultural heritage studies. However, there is little work on the development and effective use of sophisticated methodologies for understanding the interaction of visitors with cultural heritage sites.

Building on previous theoretical frameworks and methods used in similar contexts, this work examines visitors’ interaction with archaeological sites and considers the possibilities that open up from this investigation for informing interpretive planning. A critical point of this study was the development of a hybrid methodology to assess movement and spatial behaviour patterns of visitors in archaeological sites. Additionally, the methodology aims to reveal the ‘hot spots’ of such sites according to visitors’ views. This work therefore, seeks to establish a sound methodology for collecting data on the visitor experience and interaction with archaeological sites. The methodology considers both qualitative and quantitative data on movement around archaeological sites and on the things that visitors value the most during their visit and utilises a variety of digital applications for the collection and analysis of data. This paper presents the methodology developed at the Minoan archaeological site of Gournia. However, the methodology has been designed to apply to different archaeological and heritage sites. The paper focuses on the presentation of the methodology rather than the results which will be published at a later stage of this research.

1.2 From general principles to theory and practice: investigating the visitor perception for assessing interpretive planning

The interpretation and presentation of cultural heritage sites entail a series of steps from on-going research, publications, assessments and interventions (Icomos 2007). Intervening at a site - whatever the state of its preservation - is ‘an unavoidable reality’ (Ganiatsas 1996) according to the established Western view of heritage site management (Lekakis 2009); a view closely associated to the demands of cultural tourism since heritage is appreciated both as a cultural and economic commodity (Boniface & Fowler 1993, Graham et al. 2000:5).

The desire to justify public funding for archaeological research and the notion that ‘appreciating cultural heritage sites is a universal right’ as stated in the Ename Charter (Icomos 2007, principle 1) are prevalent to the recognition that ‘visitable’ archaeologies are more liable to deteriorations and damages (Hall & McArthur 1998: 107, Doughty & Orbasli 2007: 44). This existing antithesis in heritage site management is what makes interventions an unavoidable reality today and assigns heritage site interpreters the crucial task of leveraging the impact of on-site visitation in order to satisfy both the preservation requirements of heritage sites and visitors’ accessibility to cultural heritage. One of the modes for intervening to cultural heritage sites (Ganiatsas 1996, p.102) is planning for on-site accessibility and circulation of the visitors. Designing and implementing archaeological walks constitutes a critical part of broader visitor and site management strategies complementing the preventive conservation and enhancement of archaeological sites (Dimakopoulos 2000). In other words, this intervention aims to protect the site and enhance its values and the visitor experience (McArthur and Hall 1993: 242, ICOMOS 2007, Chrysanthi & Earl 2010) and it is planned as a site specific task according to the requirements of each site and the individual agendas of the interpretation specialists.

At once, relatively recent theoretical approaches in heritage studies have pointed out the importance of 'the visitor's perception' for the interpretation of archaeological sites (Urry 1990, Uzzel 1998, Solomon 2008, Lekakis 2009, Massung 2012). According to this approach, interpretive planning should accommodate the 'things we value' from our past (Giaccardi 2011) and those things derive from our personal interests, our diverse and complex way of perceiving and inquiring the remains of the past. It should not be a one off and one way process where interpretation is provided by experts for the visitors to consume. The 'visitor perception' approach also, raises some questions about the authority of curatorship and the authority of the stakeholders over cultural heritage. It is therefore imperative for CH interpreters to acknowledge that people enter these sites with certain cultural and cognitive baggage as well as certain expectations as to what they are about to experience or learn. All the above, along with the information that the site provides, form the visitor experience. However, the 'visitor perception' approach is usually left aside in interpretive planning as a factor that cannot be 'scientifically measured' (Lekakis 2009, Chrysanthi & Earl 2010).

Nevertheless, it has been ascertained that methods such as unobtrusively observing the visitor behaviour and/or engaging visitors in discussions can significantly inform interpretation planning as it provides insights about what visitors value the most and how they interact with and move within heritage spaces (Ciolfi & McLoughlin 2011). Other methods focus on tracking visitor movement and employ a variety of technologies and analytic methodologies to assess the circulation and orientation of visitors in heritage parks and historic urban centers (Shoval & Isaacson 2010, Russo et al. 2010).

A common question in such visitor centred approaches in cultural heritage interpretation is whether to engage with a qualitative or quantitative oriented research. How effective is it to measure experience and movement behaviour in such spaces and use the results to inform interpretation? On the other hand, theoretical and experiential approaches as compelling as they may be in their attempt to explore detailed individual accounts, do not seem to be enough in practical terms. Convincing other researchers and policymakers for the significance of the collected data and results entails more than presenting a few evocative narrations of the visitors' experience.

Evidently, different opinions on this matter have lead researchers to adopt a variety of approaches in evaluating visitors' interaction with heritage spaces. Often, mixed-method approaches which integrate both qualitative and quantitative analysis of data are suggested in order to validate experiential and observed findings (Bernard 2005, Creswell 2009).

2. CASE STUDY AND DATA COLLECTION

2.1 The case study

The archaeological site of Gournia is located on a small hill, a few hundred metres from the sea in the Gulf of Mirabello, in eastern Crete, an area particularly rich in Minoan archaeology.

Gournia is a typical medium sized settlement, dated to the period of the peak of the Minoan culture (Late Minoan I period: 1550-1450 B.C.). It is called the "Pompeii of Minoan Crete" because of the good state of preservation. In 1901 - 1904 Harriet Boyd Hawes excavated part of this Minoan town, revealing a system of cobbled streets, houses, a central building with court considered by some to be a small palace and a cemetery (Davaras 1989). The archaeological site today is open to the public and of all sites in the Aegean region it gives the visitor a nice idea of how a Minoan town looked like. There is also an on-going excavation led by Buffalo University and conservation works at the northern part of the site. The reason we chose Gournia for developing and testing the visitor-centred methodology for assessing the archaeological site is that apart from its well preserved ancient path system and structures, it presents a case with minimum interventions and a subtle interpretative infrastructure mainly limited but well-designed information boards.

2.2 Questionnaires and interviews

At the first data collection stage a variety of qualitative methodologies were employed such as observations, interviews and questionnaires used traditionally in ethnomethodological studies. This process revealed some of the issues that these sites face in terms of visitor management and the areas which attracted remarkable activities and interaction with the archaeological site. Apart from observations, visitors and guards were often engaged in informal conversations. It is worth noting at this point that it is truly remarkable what you can learn from such discussions about the site through the different lens of interpretation and personalised experiences. This process really enhanced our perception of what interest people from these archaeological sites, a perception based on our own biases as heritage professionals. Additionally, web image repositories (e.g. flickr and panoramio) were used to gather comments that visitors of these sites posted.

At the end of their visit, visitors were asked to fill in a questionnaire which was designed specifically for the purposes of this study. The questionnaire's structure was influenced by the Spaceshaper, a tool developed by the Commission for Architecture and the Built Environment (CABE) which works as a participatory platform for assessing and redesigning existing public spaces with the necessary adjustments based on established related surveys in the field of Archaeological Heritage Management (AHM). Apart from structured questions which include the demographics section, the questionnaire was designed to allow people express their opinion on what they valued the most during their visit or disliked the most about the archaeological site. In total, one hundred visitors took part in this first stage and provided their assessment and views on 4 basic domains:

A. The on-site accessibility

B. The spatial perception and awareness of the site's layout as they walked around; the ease or difficulty in identifying the remains

C. The aesthetics of the site; for example they had the opportunity to assess the preservation state, conservation and maintenance of the site; the contemporary structures and plantation.

D. Finally, visitors assessed the existing interpretative infrastructure and commented on what more they would like to see in a future implementation.

2.3 Spatiotemporal and image data collection

Apart from observations and the collection of qualitative-quantitative data about visitors' views of the site, tracking and recording technologies such as GPS body tracking and camera recordings were employed. Each visitor was asked to carry a small lightweight wearable GPS device. Usually visitors hung them around their necks or placed them in their pockets. Additionally, visitors were given a synchronised small digital camera and were instructed to take pictures during their visit, as they would normally do with their own camera. This data collection method was proved unobtrusive to the visiting experience and often visitors reported that they were not always conscious of taking part in an 'experiment' or that they were 'assigned a specific task'. In total, 36 GPS tracks and 644 images were collected. In terms of the GPS data quality, the open rural site, the good weather conditions and the lack of high vegetation provided an optimum accuracy reading of 3m all around the site. Additionally, the record interval was set to 'time' and the track value which was set to record every 2 seconds resulted in the collection of high resolution GPS data.

It is worth mentioning that the visitor-sourced data collection could be implemented with the use of visitors' personal mobile devices through existing geotagging applications. However, only a few visitors carry with them smartphones and most of them do not make use of them while on vacation due to the excessive roaming rates. The European Commission's strategy articulates the message that Information and Communication technologies should be treated as goods - accessible and affordable for the common wealth of societies- above and beyond the notion of 'profit'. Also, Europe's Digital Agenda includes further investments in digitizing its cultural heritage and low roaming tariffs a fact that will facilitate immensely cross-regional accessibility to heritage content and thus, data collection *via* personal mobile phones.

3. DATA VISUALISATION AND ANALYSIS

3.1 Density analysis of GPS data

In terms of processing the obtained data, a line density analysis of the visitors' itineraries was carried out in ArchGIS (fig.1). The interpretation of the processed data provided a better insight and an overview of the site's affordances for movement as well as the areas with increased accessibility. Also, some areas of the site seem to have been inaccessible to the visitors. Leaving aside the properties of the landscape itself, within an archaeological site some of the preserved features of its architectural character can afford movement such as ancient paved paths, well maintained structural features such as walls, fences and other features. Other areas leave an open and flexible option as to where the visitor can move that could be either part of the ancient planning like public open spaces (e.g. the Minoan Palaces' courts). Movement decisions are initiated from a moment of stillness; people decide to stop and observe particular structures closer and continue their interpretive exploration. Therefore, it could be argued that the environment affords stillness as well. Further time-space analysis of the captured logs can also indicate these areas.

Additionally, the interpretation of combined data from the existing interpretive infrastructure can provide an effective assessment of the use and positioning of such interpretive media. Interpretive panels play an important role in the way people move around archaeological sites, functioning as Points Of Interest (POIs) and as direction aiding tools. The analysis of the data can provide significant information about whether visitors passed by interpretation boards without reading the information, if they did how much time they spend reading them or whether the position of existing interpretive boards is the optimum for visitors and the presentation of the site. Such observations can be brought to the forefront at the stage of site assessment via this analysis and visualisation and can aid significantly future interpretive agendas.

Figure 1. Aerial image of Gournia overlaid with the density analysis results. Background image © University of California Press 1992

3.2 Hotspot analysis with Rendering and thematic classification of images

A major step towards making better sense of the collected image data was the hotspot analysis carried out in ArcGIS with the aggregated and integrated points of image locations captured by visitors (fig.2). The analysis indicated the areas that visitors recorded the most and provided another yet important interpretation of the site. In ArcGIS ModelBuilder was used to create a simple model containing a number of geoprocessing tools including Copy Features, Integrate, Collect Events, and Hot Spot Analysis with Rendering.

The analysis generated 72 unique locations the 'hotspots' which represent weighted clusters of image data. The results are visualised according to the ICOUNT field, the sum of all incidents – in this case the images captured - at each location. The red dots indicate the areas that visitors captured the most and following the colour range from warm to cold, the blue areas indicate fewer recordings. Considering that people take photographs of instances or the things they want to remember from their visit, this experiment reveals the hotspots of the site as visitors assessed them.

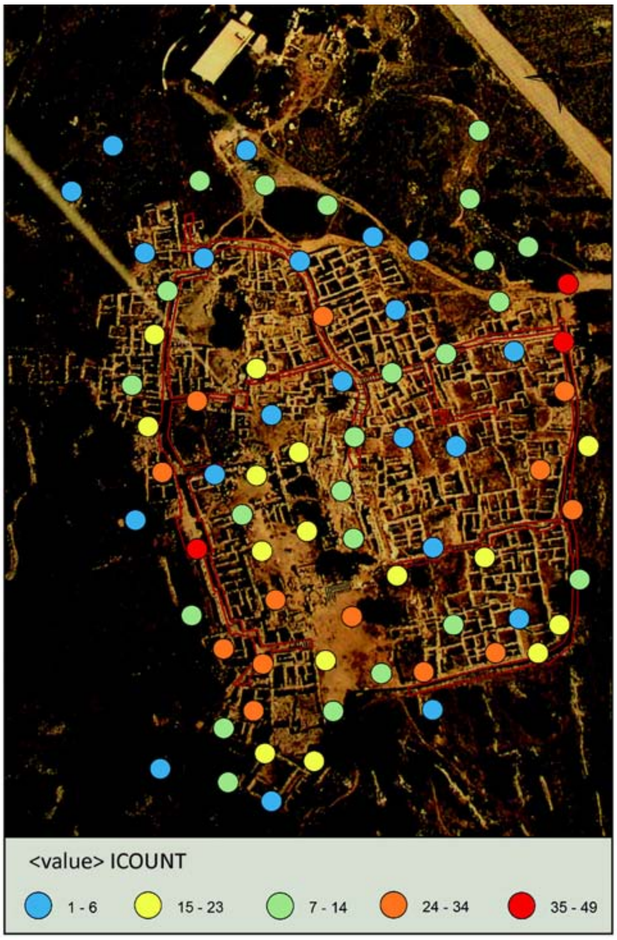

Figure 2. Aerial image of Gournia overlaid with the hotspot analysis results. Background image © University of California Press 1992

In order to identify recurrent patterns and themes in the data a thematic analysis for each hotspot was conducted according to two main questions: 1. From which spots are visitors capturing general views of the site or views of the surroundings? 2. What attracted their attention the most from the artefacts, structures and contemporary features within the site? In applied thematic analysis, codes are then typically developed to represent the identified themes. The coding system here is designed to allow a cross-site examination of the recurrent themes in each location. In the example presented in fig. the theme of the stone basins appears by 14% in the hotspot 69 and 4.5% throughout the site. Although, stone basins are spotted by the visitors throughout the site there was no information board explaining what those findings are. The main information panel by the entrance of the site which mentioned that the site was named after these stone basins was removed and has not been replaced yet.

3.3 Geotagging and spatiotemporal - visual narratives

The image data were geotagged in GeoSetter, a freeware tool for displaying, arranging and editing geo data and the metadata of image files. Both GPS tracks and image files along with other geo data were also exported in Google Earth (GE), an environment which furthered allowed the exploration of aggregated data in layers. Another benefit of displaying such data in GE, is that one can ‘replay’ visitors’ walks and the images they chose to capture and, by combining qualitative data to construct narratives about visitors’ choices of movement.

3.4 Future Work

In terms of future work, further time-space analysis is required to fully explore the acquired data. Additionally, the combination of the hotspot results and the thematic analysis with the qualitative analysis will finalise the interpretation of the data. Finally, the methodology is going to be applied at several archaeological sites which present different cases in terms of existing interpretive infrastructures and visiting modes to assess and validate the methodology.

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MODULAR SYSTEM OF SENSORS FOR MONITORING OF MUSEUMS' INTERNAL ENVIRONMENT

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ABSTRACT:

The paper outlines basic concepts of the system for indoor climate monitoring being currently developed in a four-year project. The project concentrates on building system of sensors, the related infrastructure for communication between these sensors and the server for centralized data storage and processing. The components of the planned system are highly modular for adjustment to specific requirements of given collection. The project's aim is to provide basis for remote monitoring of indoor climate and environment of exhibitions and depositories of museums, galleries, archives, etc. situated in historical buildings like castles, chateaus, town halls, where the protection of the building limits measures for indoor climate optimization. Finally the expected outcomes envisage the development of specialized sensors mainly for pest control and development of portable version of data sensing units for supervision of environmental parameters of collection during transport.

1. INTRODUCTION

The supervision and control of indoor climate in museums and other institutions keeping large collections is a key factor in long term preservation of their unique items. Preservation is even more problematic in those historical buildings where the options of applicable protection techniques are further limited by multiple factors concerning conservation issues (Camuffo 2001, Cassar 1995, Huijbregts 2012). The first important step in controlling the environment is the measurement of its parameters. Simultaneously, as a second step, understanding the relation between measured environmental variables and signs of degradation advancement in typical material classes e.g. metal, leather, paper, etc. can refine setting acceptable ranges of decisive climate variables. Both steps constitute noninvasive measures and the combined introduction and assessment of their effectiveness is a major scope of the presented project.

2. PROJECT DESCRIPTION

2.1 Project Goal and Motivation

The aim of the proposed system is to assemble a comprehensive network including sensing devices placed in the monitored indoor environment, dedicated server storing acquired data and a set of software tools and applications for data processing and evaluation.
This kind of sensor infrastructure is actually being developed in many institutions (e.g. Child 1993, Smoohs 2012). The major differences that distinguish the presented system from other implementations are on one hand the objective to interface existing heterogeneous systems and therefore to minimize necessary investments and on the other hand the attention paid to data processing and mining.

2.2 Main concept

The goal of the project is to build modular hardware platform and a unified data exchange structure enabling central processing of remote data with simultaneous supervision of indoor climate parameters and tools for evaluation of recorded data. As mentioned in previous paragraphs, the recorded data can be used not only to control indoor environment, but also for investigation of relationships between decay rate and surrounding environment for specific categories of materials.
The project has started in the year 2012 and is expected to be completed by the end of year 2015.

2.3 Reuse of an Existing Infrastructure

At the present time, sensors displaying and registering actual temperature and/or humidity, storing maximum, minimum and mean values are installed in many museums. As mentioned in the introductory part, preinstalled infrastructure can be also utilized for acquisition data without interference to its original function which is to control of indoor environment. These sensors, mainly temperature and humidity ones are used for HVAC (heating ventilation and air conditioning) systems, and also other sensors were installed and operated before start of the project. Some sensors are directly connected to the climate conditioning units, while other store the measured data till operator downloads data manually into another digital medium for further processing. The inconvenience of manually inspect every sensor and transferring data either to computer or to paper records makes the task to be very tedious work. Considering the long term, this state is also economically challenging as museum workers being highly skilled professionals, could curate and help collections more if freed from the duties to record and transmit data which can be easily performed by computers and networks. However digitized data raises some issues too: in many cases stored histories of indoor climate evolution already exists, but data is recorded in incompatible proprietary format and accessible only via commercial software limiting possibility to investigate and cross-correlate data from sensors made by various manufacturers.

Therefore the aim is to overcome these drawback and to build reliable and easy to operate system for telemetric data acquisition upon heterogeneous „ecosystem“ of various new and already installed tools, devices and sensors provided by various manufacturers in such a way that these heterogeneous sources will yield unified data structure.

3. MAIN COMPONENTS OF THE SYSTEM

3.1 General Scheme of the Proposed Network

The system is by design scalable and its architecture resembles star-like topology. The structure of the system is quite simple; it consists of an array of independent elements for data acquisition communicating with the data server over Internet using standard protocols and custom written software. Data acquisition elements consist of control unit, sensor interface and communication unit. The variability of attachable sensors, as well as communication means makes this element of the system a powerful and universal tool for remote data sensing.

The main reason why the whole device contains separate sensor interface is the requirement to select variables important for given collection individually. Similar argument is also valid for communication unit that is equipped with technologies according to connectivity at a given location. In the block diagram in the Figure 1 the basic components of the sensing part of the system are depicted.

3.2 Components of Basic Element

The developed system’s basic element is modular, designed to interface variety of sensors. Deployed units can be either powered from mains or by battery. The control unit is able to store data in the case connection to server has been interrupted. Sensors consuming the minute amount of energy and working discontinuously can be considered as the best candidate for this approach. The challenge consists in building them independent on external power supply by harvesting local sources of energy. Sources of energy available on-site, like temperature gradient, wind draft, vibrations (e.g. Glynne-Jones 2004), electro-magnetic radiation or illumination or other forms of energy will be considered.

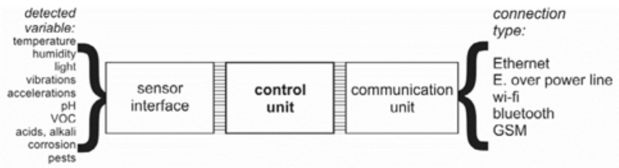

Figure 1: Components of system elements

3.3 PC Based Unit

Most important part of the basic element is the control unit. In order to provide room for future scalability and possible functionality upgrade, the central units are not based on dedicated or custom built chips and circuits, but they utilize flexibility of PC based board with chipsets providing the interface to standard and industrial peripherals and sensors. In order to make interfacing to “dumb” sensors possible, it is necessary to provide the control unit with enough computational power, because it would be necessary to convert data mentioned for human information but not for data transfer. These units represent fully equipped PC-compatible devices.

The major advantages of the adopted solution are simplicity of programming and interfacing other devices. In addition to these, it is possible to outline the following benefits:

- Small form factor for easy miniaturization;
- Energy efficient components limiting power consumption and also release of heat, implying that the device can work on backup battery for a long time (weeks) without interrupting its task to acquire and store data;
- Linux based operating system provides a luxury and development throughput of high level programming language in comparison to coding specialized chips in machine code;
- Devices can be accessed and their software can be upgraded or repaired remotely;
- The price of the device is quite low, especially when compared to commercially produced systems;
- Extensive amount of peripherals and add-on boards is available on the market;
- Huge user community providing for help and development assistance.

At the present time, there are known several manufacturers producing these integrated PC board like e.g. Arduino or ALIX (Arduino 2012, ALIX 2012). In this project, ALIX board is used. It is a miniature form factor system board optimized for slim clients and embedded applications.

This unit provides connection to the sensor interface and also to the communication unit. The first prototype is shown on Figure 2.

Figure 2: Prototype of the control unit

3.4 Sensor Interface and Measured Parameters

The interface to the sensors is compatible with the vast majority of sensors available on the market. This domain is in a fully developed stage and the market offers sensors for any measurable property. Therefore knowing material, composition of collections, decisive parameters and suitable sensors can be easily selected. Database compiling knowledge on dangerous environmental parameters for major types of materials can serve as a starting point in this attempt (Dvo áková J. 2001).

It was shown that indoor environment can be characterized by several parameters measurable by exploiting various physical and chemical principles. The most common parameters are temperature and relative humidity. Depending on collection type, other important variables are the exposition to light, to ultraviolet radiation or to thermal radiation. It is necessary to distinguish between these three radiations as they trigger different decay processes in objects, based on their composition and structure. Another key class of sensors detects corrosive agents in the indoor atmosphere. These devices are based mainly on a vibration member equipped on its surface with a layer of investigated metal. As oxidized or corroded layer builds up it causes the change of its resonant frequency which is measured in some close-loop setting. The presence of dust and other particles in the indoor air is also important parameter. These particles are usually counted for and the distribution of their sizes can be also measured. VOC, volatile organic compounds are considered dangerous especially for organic components which are sensitive to them. Among other detectable properties accelerations, vibrations, chemical properties like various gases, acids, pH can be named. Where necessary, these sensors will be attached to the sensor interface.

3.5 Specialized Sensors for Pest Control

Pest control is an important issue in collections' protection. In order to keep insect infestation low or to eliminate it completely, the collections undergo preventive measures involving regular application of gas toxic to the insect. These measures are adopted even if there is no sign of pest presence. The reason why this crude approach is chosen can be found in the fact, that there are no effective sensors detecting pests' presence in the collections. In order to overcome this situation, specialized sensors based on combination of chemical attraction and image analysis methods are to be developed. Their use would allow taking qualified decision if the gas has to be applied. This would reduce exposure of workers in museums to these potentially harmful substances and also save resources.

3.6 Communication Unit

Depending on the situation, the control unit either stores data locally or transmits it to the dedicated server via communication channel available at the given location. The data transfer is provided by communication unit attached to the central unit. The internet connection can be carried out over metallic line, the power lines of AC 220 V can be also utilized, as well as wi-fi, Bluetooth or GSM modem wireless connection (see e.g. Gungor 2009).

3.7 Setup for the Use in During Transport

Transportation is a risky task and represents a serious threat to objects in collections, therefore precautions are necessary. Portable elements of the system can be used to on-line monitor collections during transport and to record whether conditions remain in predetermined range – this applies especially to location, temperature, inclination (allowed orientations range), acceleration and vibration control.
Introduction of sensors recording conditions during transportation can be used as a tool imposing negotiated parameters of collection's transport with companies that provide the service.

4. SERVER AND SOFTWARE

4.1 Hardware Part and Its Main Functions

Building of the system includes development of dedicated server for data storage, processing and presenting. Data is stored centrally and available on-line for supervision of collections by responsible personnel and also for extensive data-mining. Other requirements laid upon the server are system management, mirroring, backup, uninterrupted operation, hot-swap, support for UPS, etc. The server runs the database server, the web server allowing simultaneous execution of applications, the warning system and the data mining. The main functions of the server are shown on Figure 3.
Central unit stores data records in a uniform structure and processes them „on the fly“ for immediate response if data indicate abrupt change or are placed outside acceptable limits. In the long-term the unified and centralized way of storing data will allow to assess what parameters and what thresholds are permissible for collection preservation. Upon combination of models and recorded data, it would be possible to deduce trends of measured parameters and therefore to refine the climate control and to prevent loss of value.

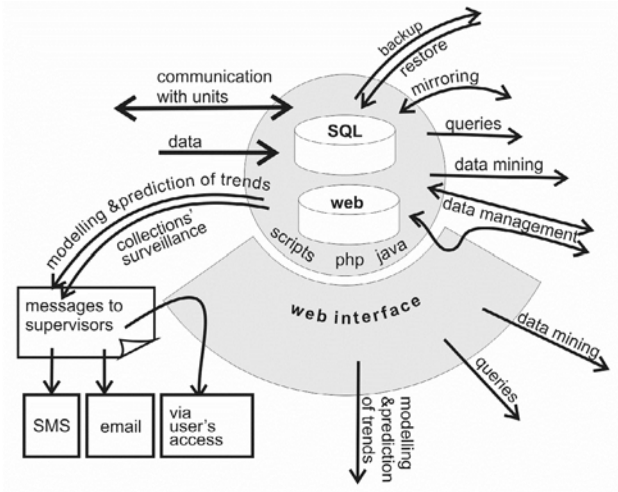

Figure 3: Schematics of major function of system's server

4.2 Software and Data Processing Part

Along with hardware development of basic elements and server, data processing applications are to be built. A unified structure of data enables finding characteristic changes in patterns of indoor parameters, which can be related to deterioration of collections' objects.
In contrary to the most cases, where acquired data is used for optimal indoor climate control without being stored for consequent processing, this project can be distinguished from other projects of this kind based on the attention it pays to use and processing of centrally stored data. Unified data structure relying on sequential stream of data records mimicking the way data is acquired by sensors, as well as XML (Extensible Markup Language) metadata for semantic annotation important for computer "understanding of stored data" simplify data processing and evaluation. The record's structure allows for effective selection of studied location, timespan and variables in the first step and investigation of mutual cross-correlation between phenomena in the second step. Dedicated routines watching whether measured values of parameters fit into preset interval deduced from requirements of the most sensitive material in supervised collection are also provided. In the case the threat to the protected collection is detected, this routine triggers sending warning messages to responsible persons via email, sms or user account. Signal from every sensor would be also statistically evaluated to provide user with values representing properties of measured signal like mean, standard deviation, etc.
Design of data structure involves SQL relational databases, unified data format, XML metainformation, tables summarizing information on buildings, rooms, sensors, units and also on collections, their prevailing materials and tables of material

sensitivity to various environmental variables. Database is to be built following rigorous rules, like exclusion of information redundancy in tables, etc.

A sensible balance in database tables design has to be established between simplicity for easy maintenance and ability to express significant relations in sufficient detail. For example, it is useful to keep information on rooms and control units separately, as there can be unit connecting sensors in two adjacent rooms, as well as two separate units can be placed in the same room. Figure 4 illustrates the situation.

Figure 4: Objects and their relations in the database (museum building, rooms, units and sensors)

4.3 Data Mining

The aim of extended data processing and analysis is to investigate correlations between collection's state and recorded parameters of indoor environment. These ad hoc interpretations of records (that play role of observation in laboratory tests) are the only "experiments" allowed to be carried out on objects in collections. Limited museums' budget, especially in such an age of austerity measures, implies that many collections are kept under sub-optimal conditions. Also protection of historical building of museum limits the extent in which indoor climate can be controlled, therefore it can be in conflict with requirements of collection (La Gennusa 2008). This situation is not an immediate threat to the objects, but minor signs of deterioration can appear. The seemingly inactive observation, in fact, successfully assesses the dynamics of deterioration of collections consequently allowing to intervene prior irreparable damage occurs to objects.

5. DISCUSSION AND CONCLUSIONS

The final goal of evaluation of stored data would be better understanding of decisive indoor climate parameters from the point of view of collection protection and mitigating decay of its objects.

One of the contemplated applications exploiting the accumulated data would be the adjustment of ranges of safe or acceptable margins of environmental parameters for storage of various types of materials. It would be also possible, in the case of the simplest materials, to combine recorded indoor climate data with so called dose-response functions for rate of degradation prediction (Tidbald 2001). These dose-response functions are determined empirically and relate material degradation rate, like corrosion rate in the case of metals, with concentration of some pollutant or with other parameter, like relative humidity. Similar approach has been adopted for determination of decay of elements of historical buildings as a function of atmospheric pollutants and e.g. rainfall in EU-funded project Cultstrat (Watt 2009).

The importance of comparative studies for understanding deterioration mechanisms of objects in collections is evident. The investigation of correlation between degradation of materials and objects and the indoor climate allows evaluating sensitivity of studied material on various environmental parameters. It enables museum workers to estimate influence of indoor climate parameters on objects' decay without actually performing any tests destructively. Therefore, in such a way, safe margins of indoor climate preparation can be determined.

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PRELIMINARY IDEAS FOR A PROJECT ON CULTURAL HERITAGE:"HEVA"- DIGITAL RESOURCES OPTIMIZATION FOR THE ENHANCEMENT OF CULTURAL HERITAGE

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KEYWORDS: Data Transmission, Cultural Heritage, Digital Resources, Photogrammetry, Virtual Reconstruction, Interoperability

ABSTRACT:

Cultural Heritage documentation by itself is meaningless if it does not help to create wealth and provide values to society. In recent years, the number of digital contents related to cultural heritage resources is growing in a way that it very difficult to discover reliable information. Thanks to the Internet they can be easily published and distributed but there are three main problems: 1) the quality of the resources is not well evaluated or tagged; 2) the resources are fragmented across several non-linked repositories; 3) most of the resources are not adapted to different kinds of devices and users. These problems are more remarkable in point clouds and three dimensional models digitalized at high resolution, to achieve a higher level of detail because they are too heavy for visualization, transmission and representation.

The present statement of intentions aims to develop a project –HEVA: HEritage VAlue– for creating an effective methodology to simplify and improve the exploitation and transmission of cultural heritage documentation in the three most relevant fields: culture, education and economy. The main goal of the project is to reformulate the objective of cultural heritage documentation from a sustainable perspective, linking the efforts to the achievements and optimizing the processes. At the same time, the project will create synergies between multiple agents involved in documentation, allowing an intelligent diffusion of cultural heritage such that heritage can reach interested people, people who really want to be reached.

1. INTRODUCTION

From the early nineties there has been a very active policy involving Cultural Heritage issues in the EU. A recent short survey is given in [1]; a more extended presentation can be read in [2]. Furthermore constructive and technological aspects, some crucial issues involving the whole chain value knowledge transfer, educational training and a sustainable management. In the current economic crisis, these issues have increased their relative importance in view of their social impact (including transferability), economic impact (for specialized jobs linked to CH activities) and policy impact, especially in countries of the Mediterranean basin, where a very large amount of CH is concentrated. The current economic crisis has transformed social interactions and their sensitivity to exchange processes where economic calculation evaluates the property for his extraction cost rather than replacement cost. The emphasis on its extraction and production of new content / products against recovery and recycling of existing ones, increase the distance from the behavior of civilization against different models of sustainability.

Cultural Heritage is a very important part of European quality of life and increasingly valued by the international community. The teaching-learning relationship on Heritage not only generates a conscience about the needs of the proper management of values and assets, but also encourages collective development processes, setting the stage for continued economic-cultural-educational growth and enrichment. In addition, it provides a support for integrated approaches to environment to maintain natural and historic resources and to improve the management of heritage sites. Thus, it contributes in a very meaningful way to add social and economic value to cultural assets.

The **economic value** refers to the capability of promoting and providing a support for economic activities around the existence / loss of a known patrimony such as virtual tourism (which is then translated into actual tourism) and the virtual reconstruction (which lets you overlay additional content on the existing assets). Much rethinking is needed as to how 3D models can provide a support for inserting additional contents linked to web services in order to create wealth while posing a precise documentation of heritage, able of stimulating the demand of CH assets and promoting Heritage Tourism.

The **educational value** refers to the enrichment of knowledge which can be achieved with digital documentation of heritage at different levels (from school children to scientists) and at different layers. Currently there are a lot of books, pictures, videos, 3D models, etc., which in the current situation need to be reorganized in an appropriate manner and linked to a common digital object. The project HEVA: HEritage VAlue tries to answer to the following question: How can we perform the transfer of multiple meanings of the object from digital assets? 3D models tend to forget the essence of each item and stay at a formal level without other contextual information. HEVA is intended to assess the documentation to label with enriched contents to complete documentation suitable for education.

The **cultural value** refers to the possibility of knowing, not only the local culture, but other cultures or spread their own, also. The artistic language barrier makes it difficult for the general public access to distant patrimony. The project HEVA: HEritage VAlue alleges that the documentation of heritage help spread our culture beyond their physical boundaries by means of images, models and symbolic representations. It intends to redefine the objectives of heritage documentation to create wealth, increase global culture and to understand from primary education the essence of heritage.

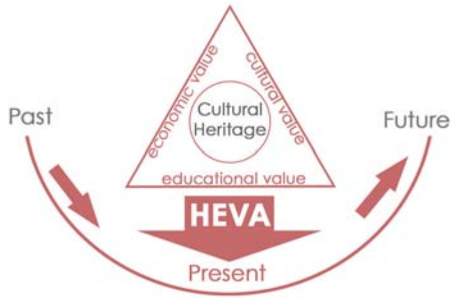

Figure 1: Management Plan for Cultural Heritage in HEVA Project

The Management Plan for Cultural Heritage in HEVA: HEritage Value, shown in Figure 1, is a response to the current economic crisis for a model of enhancement the heritage of a more sustainable view (see Figure 1). For example, if we search Google 3D Warehouse the term "castle" get more than 3000 3D models, this raises the question of whether they are actually effectively used or enjoyed are the result of individual effort without additional incidence for the whole community interested in CH assets.

The experimental study of the processes of cultural heritage management, with emphasis on research associated with the functional standard methodology, involves the acquisition of new knowledge from the underlying fundamentals, allowing a better understanding of the past, and thoroughly, our present to improve the future. In other words, 3D modeling is not a goal by itself; it must be a mean to improve the sustainability in social and cultural policies. Sustainability is understood as a harmonious balance between environmental, social and economic factors. Hence, the system becomes increasingly unbalanced and thus unstable for future generations if the economic component is not sufficiently valorised, bringing with it social, educational and cultural components degradation.

1.2 Motivation / Hypothesis

The proliferation of multimedia digital documents on patrimony, fragmented across multiple repositories and, non-adapted to different visualization devices, causes a decrease in its value and therefore a lower return of the initial investment. Facilitating the diffusion and reutilization of digital content maximizes the cultural, educational and economic Cultural Heritage, at the same time contributing to a sustainable development model. The research in new approaches involves technologies, tools and algorithms, that facilitate the connection and exchange of digital content and adaptation to user's device, will allow to extend the range of possibilities for the dissemination of tangible cultural heritage. The main goal is to improve the quality of the documentation of heritage, the way it is retrieved and displayed, as well as navigation on related information available on the Web, will increase interest in heritage and its exploitation and transmission to future generations. Our starting hypothesis is that this goal can be achieved from the development of a distributed scheme by sharing data infrastructures and smart software tools for knowledge management in a collaborative environment. This hypothesis involves to (a) the development of Semantic tools for integrating and developing the current data infrastructures, and (b) the articulation of a network of communities of users and developers (in terms of Living Labs, mash-ups) for profiting the benefits of DIMAS integration

1.3 Aims

Regarding developer and user communities, the current project pursues as a main objective the simplification and improvement of the current processes for the enhancement and dissemination of Cultural Heritage. Manual insertion of digital CH contents is a very cumbersome and high cost task. Hence, it is necessary to develop a bottom-up approach allowing different agents to participate according to a minimal set of rules. One of its main contributions is the definition of a strategy and methodology for assessing the digital documentation of heritage in implementing outreach strategies related to the fields of CEE (Culture-Education-Economy). Interoperability issues are being solved at the technological level, but not still to the level of management systems involving diffusion and reuse of the available information in web accessible repositories.

As was explained at the beginning of this section, the methodologies currently used for the documentation of heritage are focused on generating a reliable and accurate documentation, but not in its diffusion. This project will research new technologies, especially those related to the Future Internet, that can help in different aspects of diffusion processes such as reliability, the discovery of related content, transmission and representation (see figures 2 and 3). These issues involve to the articulation between Information and Management Systems supported by the Documentation System.

Figure 2: Generation of documentation for diffusion: Documentation of the Royal Pantheons of Santes Creus Monastery for the Museum of Cataluña (Barcelona) Spain

Figure 3: Generation of documentation for diffusion: Virtual Tour of Holy Trinity Church in Segovia, Spain

2. ANTECEDENTS AND CURRENT STATUS OF KNOWLEDGE

The digital documentation of heritage consists in capturing real information of objects with high patrimonial value and stores it in digital format [4] [5]. For making reuse easier, the documentation must be performed according to protocols and stored according to key words

Once the contents have been generated, they enter in a cycle of life [6] which must be conveniently exploited to recover the initial investment. The information generated is stored as byte stream that can only be interpreted by programs that generate and is not suitable for transmission (because of its high weight) and for integration / reuse in diffusion processes. Therefore it is necessary that in a second phase describes the content in metadata terms so that they can be interpreted and used not only by humans but also by machines without the need of inspecting their contents. The lowest level recommended by the EU is given by DCS (Dublin Core Standards). Their adoption is a first step for guaranteeing the interoperability and the reuse of materials contained in digital repositories.

The generation of metadata and annotation / labeling of the content may be done manually or automatically according to general principles of semantic approaches [7]. Automatic labeling needs advanced expert systems able of recognizing digital contents. Semiautomatic recognition includes to design and implement query, localization, extraction, annotation, classification and indexing procedures.

Once the data has been properly recognized, it is necessary to proceed to the management phase of digital content. Along this stage the documentation is stored in repositories that are currently isolated. This makes it difficult the recovery and discovery of digital content as it is not accessible from an external position. Currently, the solutions are based only on the conventional Web 2.0, allowing to close the cycle with the development of recycling and exploitation of digital contents.

Over this known basis, this project intends to advance in the current knowledge regarding various scientific and technological issues related to the architectural heritage documentation, among which include:

- **Topography and Digital Photogrammetry**, which allows digitize the objects to turn them into digital content easier to transmit, nevertheless the problems linked to the preservation of digital archives [14]. Today, thanks to new technologies, improved accuracy and cost, it is possible to have a cheaper generation of CH contents from different 3D reconstruction hybrid techniques based on a combination of images correspondence from multiple views, laser scanning technology based on time of flight, phase difference and triangulation, etc. [18].

- **Computer Graphics and Computational Geometry,** are the disciplines that study the representation of 3D models in 2D/3D visualization devices and management of meshes at different resolutions and in-memory representation structures [22]. Related contributions of HEVA Project include a universal display platform, and the detection of the shape and automatic simplification of 3D models to be adapted to visualizers.

- **Future Internet** which is understood in the sense of involved technologies, with special attention to the development of Web 3.0. The development of this framework for CH digital contents makes it possible to discover, publish and communicate the digital documentation of heritage already available, as well as that subsequently generated. Some of the technologies involved are: the Semantic Web, including the use of ontologies [16], the Web Services for connecting different repositories of documentation [20], and Web Media that allows to adapt, simplify and transmit in real-time the documentation, especially the 3D models. The application of these technologies to the heritage will enable to obtain a new structural framework based on a Web Oriented Architecture or WOA [21]. Using this architecture it is possible to abstract the recovery and visualization of the contents of the type of device that uses the end user.

2.1 Current status of related research groups

At the national level (Spain), the main research groups related to the heritage documentation, are the Heritage Interpretation Laboratory (UAM), the Photogrammetry and Laser Scanner Research Group (UPV), the Laboratory of Geometric Heritage Documentation (EHU) and the Group of Historiography and Andalusian heritage (USe). Currently, its research focuses especially on improving and cheapening the photogrammetric documentation of the assets, so that expected results are related with the same problems which are addressed in this project. Other institutions, laboratories, and interpretation of heritage groups, which are working with CH digital documents, continue even without addressing the problem of diffusion of the generated documentation in an effective way, which often ends isolated and neglected for being difficult to maintain.

Internationally there are several groups in Europe that are already addressing the goals of this project, although the results are still partial. FORTH-ICSS group (Greece) and CGV, TU-Graz (Austria) are developing an infrastructure or environment, which combine information retrieval and management of digital content. The ISTI-CNR Italian Institute addresses the same problem, only applied on document images of ancient texts. The Semantic Computing Research Group (Finland) has developed technologies and applications within the Semantic Web for heritage management, leaving aside the content adaptation and annotation, which are performed manually. They are the most actively involved in the maintenance of the CIDOC CRM ontology using a semantic browser.

For the development of the present project, it is essential to incorporate RTD groups with expertise in Photogrammetry, Computer Vision, Computer Graphics and Semantic Web. The Laboratory of Architectural Photogrammetry (LFA) and Modeling, Biomechanics, Advanced Visualization and CH (MoBiVAP) Group, both from the University of Valladolid, subscribers of the current project accredited a rigorous participation in the proposed topic with more than 40 publications and 30 projects / contracts in the last 5 years. Also, both groups have worked on other projects of applied and fundamental research whose results motivate the research proposed for HEVA: HEritage VAlue. Next, we shall comment some of recent achievement performed by this Spanish cluster.

The project **MAPA** (Models and Algorithms for the Architectural Heritage) was focused on the digitization of patrimony and the technologies that would enable a more accurate and reliable documentation. The main result of this project was a framework for generating accurate and realistic 3D documentation, combining information from different digital sources. The project **ADISPA** (Analysis, digitization and interoperability in the Architectural Heritage) raised the problem of connecting different tools, repositories and agents involved in both the digitalization and diffusion processes (see Figure 4). The results of this project (still in progress) show the need for a deeper research of new methodologies and technologies to simplify the reuse of digital content resulting from the documentation of heritage.

Figure 4: Different physical tools show different digital content. Church of San Isidoro, Spain, Project ADISPA.

Finally, the results of PATRAC Project (Accessible Cultural Heritage) showed that physical spaces and digital documentation of heritage can be accessed from multiple devices to many types of users, and provide a support for advanced interaction as web services in complex CH environments. This support has been developed with a special attention to persons with motor disabilities (devices mounted on a wheelchair) in a monitored environment A natural extension of this approach includes advances in technologies related to Future Internet, which are of great interest to explore new ways to transmit and communicate the value of heritage through the Web.

The above antecedents allow the involved groups to put in practice previous knowledge and expertise. Innovations and relevance of HEVA: HEritage VAlue objectives are related to the creation of an infrastructure or framework to facilitate the integration, the transfer of knowledge and interaction between different agents involved in the Heritage diffusion . This infrastructure will bring benefits to local and regional institutions (such as a political assistant to maintenance and restoration), to companies related to task analysis, rehabilitation, visualization and diffusion and academic entities themselves. To achieve this, it raises the following specific guidelines:

1. Develop a methodology for assessing the quality of documentation based on the peer review mechanisms.
2. Study on the diffusion current needs of World Heritage in the areas of Education, Culture and Economy
3. Connect documentation from multiple repositories, in multiple formats, enriched with metadata with a shared common vocabulary (ontology)
4. Design and implement algorithms for automatic annotation (metadata extraction) of digital content.
5. Design amd implement algorithms for automatic labeling of parts of 3D models based on recognition of shapes, colors and other geometric and radiometric characteristics of the models.
6. Facilitate simultaneous access to real-time digital documentation, updated from multiple devices using Web standards like HTML 5.
7. Adapt the quality and quantity of digital content to devices and users.
8. Evaluate the improvement in Heritage diffusion as educational, Cultural and Economic products, by reusing digital content.

3. THE PROJECT

3.1 Directing the research

The research is based on the current context within the documentation of Cultural Heritage. Consistency with the various institutional and government policies (national and international) will be another tool that will promote the conservation of historical heritage through the diffusion. Currently, there exist a lot of official directives and recommendations contained in different charts (Lisbon, London) arising from the European Commission which have been specified in strategic objectives of several Framework Programs involving Construction and ICT areas. These strategic objectives are linked to Strategic Research Agendas (SRA) of Technological Platforms which provide a common support for developing a public-private collaboration with an important incidence at national and European level. These initiatives have been grouped in a JPI (Joint Programming Initiative) on ·Cultural Heritage and Global Change: a new challenge for Europe" which extends these goals to the 2020 Horizon. An important goal is to promote the research and innovation in CH involving the whole value chain, increasing the impact, the mobilization and engagement of different stakeholders in a shared environment.

A crucial technology issue included in HEVA Project is to try to solve the interoperability issues concerning management. This solution improves the sustainability of CH assets because it allows to incorporate available resources in a common semantic framework which is managed by words and sentences of ordinary language. It allows to incorporate advanced software tools (contents extraction, recognition) provides a support for developing new techniques (as the linked to Virtual Tourism as previous to a physical visit), and allows the incorporation of large amount of digital contents in a collaborative framework. In particular, in HEVA: HEritage VAlue we develop a combination of Reconstruction and Recognition tools managed by a semantic framework, which facilitate and cheapen the processes of digitization, retrieval and diffusion. Let us remark that tourism industry generates an estimate annual revenue of EUR 335 billion at EU level, and many of the 9 million jobs in the Tourism sector are linked to CH [3]. Thus, the return to citizen policies is warranted because heritage tourist activity is an important source of economic income that occurs, generating direct and indirect revenues and providing added value for their social benefit, even if their effects are not measurable in the short-term

Although the first needs to technological level arise in the area of heritage documentation, to address a global solution it is necessary to carry out a multidisciplinary research process that involves different disciplines. The major research groups can be classified into three: generators, captors and diffusers. All of them can be interpreted as different stakeholders who need a common and easy-to-use framework for sharing experiences and knowledge through their common language. This layered framework is organized at different levels and with different profiles according to their role:

The **generators** produce documentation to create wealth and provide support for education and spread of specific cultural values. This group includes educators, archaeologists, historians, etc. The **captors** provide the processes, technologies and tools for reuse or recycling of the currently existing documentation, integrating it with the newly generated. This group includes mathematicians, computer scientists and other technologists. The **diffusers** endow social impact to the contents, using mechanisms based on new communication networks. This group has reporters, communication experts etc.

3.2 Basic Structure

The structure of the work will start from generation of metadata and annotation / labeling of the content. Faced with the existing approaches that address this problem manually, in the project HEVA: HEritage Value, will be studied in depth the intelligent allocation of second level metadata from advanced recognition tools applied to CH knowledge domains.

The semiautomatic annotation of 3D objects is another area of research that deserves special attention. Currently there is no format that makes it possible to represent and exchange 3D models described with a generic vocabulary. The project will advance in the development of an open XML-based format for transmission of 3D models labeled items. In this case the labeling of parts of the model can be addressed automatically using recognition algorithms based on multiple characteristics [8]. The recording of the parts of the model can refine the search results and provide the user a richer experience which must be translated to syntactical constructions for CH assets. To avoid an excessive generalization, we restrict ourselves to some meaningful examples arising from civil and religious architecture of Middle Age and Renaissance.

To solve the problems posed by the storage of documentation in isolated repositories and limitations that involve the Conventional Web 2.0 solutions (consist of posting links to content in multiple forums [6]), the project HEVA: HEritage VAlue will use the approximation *Linked Open Data* (LOD) [10] [11] from the Semantic Web in which resources are identified by their URL and annotated with the vocabulary of an ontology.

In this same phase there is the problem of reliability and quality of content retrieved, an inherent problem to information published on the Internet [13]. Within this framework is where the HEVA project proposes the development of a valuation methodology based on peer review of content. At the present the majority of strategies to address this problem do so from the standpoint of the visitor comments, where all are equally important. This methodology will be adapted and improved in this project.

Finally, the last phase of life cycle involves the reuse and exploitation of digital contents. At this stage, CH contents are recovered and visualized by users on different platforms. While current solutions consist of developing applications for each type of device to display the contents stored in local repositories, in HEVA: HEritage VAlue, will deepen in the use of Web standards like HTML 5 and WebGL [14] to develop a browser of digital content associated with multi-platform heritage documentation, in which the contents are adapted [15] according to the type of device and transmitted in "streaming" in real time [16]. The point clouds are the type of content that presents a more complex research in this area. In the case of 3D content these will be browsed by the user from the device itself.

3.3 Development phases

The general methodology to be followed during the project HEVA follows a bottom-up approach. Our proposal part of the efficient creation of 3D models as a common reference to add economic, educational and cultural value to cultural assets, with the design and implementation of tools and techniques for valorizing CH assets in multiple ways, formats and layers. These ambitious goals must integrate Documentation, Information and Management Systems (DIMAS) in a common framework which is given by the Semantic Web. This integration is feasible thanks to the design and implementation of a specific Ontology for CH.

The capture of CH information, assessment processes and the articulation between Information and Management Systems supported by the Documentation System will be addressed throughout different tasks and processes, supported on previous or on-site acquired documentation of archaeological sites, urban-architectural areas, and industrial centers, generated in the first part of the project.

The final results will be validated by a qualitative and quantitative assessment of the number of accesses and the consultation time of the digital documentation of heritage in a national pilot experiment. It will also include subjective assessments of experts in each areas in which the Heritage diffusion is essential (culture, economy, education). These assessments enable a review of the impact that the project results have on the community of actors involved in equity, as well as the achievement degree of the project objectives.
The process is developed under the following phases:

Ph1. - Study and collection of requirements associated with Heritage diffusion. It attempts to capture the real needs of the different types of end users that exploit the added value of digital documentation of heritage. In addition, will be scheduled the documentation of different patrimonial scenarios that will be used as test data for the experiments in the following tasks.

Ph2. - Elaboration of a methodology for evaluating the quality of the documentation: It will improve the mechanisms and procedures currently used for the valuation of digital content and, by extension, the documentation of heritage for supporting additional contents (information and management systems).

Ph3: Creating Standards for Heritage documentation from the principle of maximum efficiency: The application of new technologies compatible with the needs of the context and objectives in the field of heritage diffusion will consider modeling quality products, as well as economic / time costs.

Ph4. - Designing an infrastructure for content publication: The distribution and current organization of documentary heritage repositories follows a structure of silos, which makes it difficult the integration in real time. The use of Web technologies to establish a WOA architecture in which contents are interrelated and are automatically published without waiting for its indexation (as happens with Web browsers 2.0) can help to solve this problem. Thus, the documentation can be accessible by reusing existing content.

Ph5. - Designing algorithms for the labeling and automatic semantic annotation: The aggregation of metadata about the documents is a very expensive task, especially when these are great data volumes of ancient documents. The automatic realization is far from being perfect, so there is still much space for improvement. Main contribution concern to algorithms for automatic discovery of metadata, as well as automatic labeling of meaningful regions of 3D models instead if treating them as a whole. This is especially useful for complex façades, buildings or large urban area that has been rebuilt with different styles and technologies.

Ph6. - Designing of easier end-user applications for the adaptation of content to the device: Getting better dissemination of heritage by enhancing the perceived user experience. To make this entirely satisfactory it is necessary that digital content that can be recovered, can be easily adapted to preferences and characteristics of each device (especially to the display and its processing capacity).

Ph7. - Developing a browser and a multiplatform viewer of digital content: Integrating infrastructure resulting from the task S3, content annotated with the results of the S4 and algorithms adaptation and recommendation of the S5it is possible get a Web environment that can be used from multiple device types, regardless of underlying operating system. The result of this task will simplify the access and diffusion of heritage documentation to the different actors involved in the process that will have access to the latest information simultaneously and in real time.

Ph8. - Evaluation, valoration and diffusion of results: The results of the preceding tasks need to be evaluated and validated in order to quantify the degree of fulfillment of project goals. It is able to demonstrate that new technologies help to improve the diffusion and the valorization of patrimony over the current situation, on the other hand presupposes the validation of the hypothesis of the project.

3 CONCLUSIONS

Understanding that the text does not respond to a realized project but preliminary ideas, research development marked by the standards and methods set forth herein, allow "putting in value" to the CH by digitization, interoperability and flow of their assets material and immaterial.

In the scientific-technical section, HEVA: HEritage Value will develop models, tools and technologies for segmentation of 3D models, adaptation and simplification of content to the user and the automatic extraction of metadata from large repositories. In addition the project will enhance and improve the knowledge about the dynamics of the processes of dissemination and exploitation of architectural Cultural Heritage, assessing the perception that users have over the heritage and improving the methodology to assess the quality and reliability of digital documentation.

The results of the project HEVA: HEritage VAlue will contribute, in general, to the improvement of processes for heritage diffusion by developing an open, reusable, standards-based Web, which will be recyclable in different systems of management of digital content.

The presented ideas represent not only an enhancement of the documentation of CH assets, but will contribute to progress in some challenges involving standardization with obvious implications in interoperability between different systems and sustainability from EEC viewpoint. The achievement of the proposed guidelines will allow to identify the most promising or more deficitary areas will require further study. The need for interaction with techniques and latest design technologies imply a risk of obsolescence as the proposed tasks progress, being necessary periodic evaluation procedures for the adjustment of interests in relation to the evolution of national and international studies/policies involving CH assets.

From a global viewpoint, the action field of HEVA: HEritage VAlue is defined by mobile margins in different knowledge fields involving digital photogrammetry, computer vision/graphics. Hence, the proposed statement of intentions must be understood as a flux between different communities interested in CH assets to improve delivery of products, services and governance tools involving cultural, educational and economic resources and according to European directives

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A PHOTOGRAMMETRIC ANALYSIS OF CUNEIFORM TABLETS FOR THE PURPOSE OF DIGITAL RECONSTRUCTION

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ABSTRACT:

Despite the advances made in the recording and cataloguing of cuneiform tablets, there is still much work to be done in the field of cuneiform reconstruction. The processes employed to rebuild cuneiform fragments still rely on glue and putty, with manual matching of fragments from catalogues or individual collections. The reconstruction process is hindered by inadequate information about the size and shape of fragments, and the inaccessibility of the original fragments makes finding information difficult in some collections. Most catalogue data associated with cuneiform tablets concerns the content of the text, and not the physical appearance of complete or fragmented tablets. This paper shows how photogrammetric analysis of cuneiform tablets can be used to retrieve physical information directly from source materials without the risk of human error. An initial scan of 8000 images from the CDLI database has already revealed interesting new information about the tablets held in cuneiform archives, and offered new avenues for research within the cuneiform reconstruction process.

1. INTRODUCTION

The term cuneiform is often used to describe an ancient logographic script that has it's origins in Mesopotamia, the area of the Tigris-Euphrates river system that includes modern day Iran and Iraq. Cuneiform script is distinguished by the characteristic wedge-shaped impressions that form the sub-elements of each symbol. Cuneiform is most frequently found on clay (or stone) tablets, seals, and markers from the ancient near east.

Cuneiform tablets vary in size from approximately an inch to (in some cases) over a foot in length(Anderson, 2002). Despite the implications of their taxonomy, the term 'tablet' may refer to one of a number of shapes. The most notable deviations from the expected form of a clay tablet can be found in collections of seals and stamps, which may be cylindrical or even spherical in their geometries. Other 'tablets' may be conical, cubic, prismatic, or rectangular in appearance(Walker, 1987).

The historical data contained within the clay tablets is diverse, as would be expected from a civilized culture in the height of its development. Cuneiform is used to convey information on mathematics, law, medicine, contemporary events, shop inventories and orders, educational matters, royal decrees, and certificates of authenticity from traders.

The intellectual diversity of the tablet contents is matched only by the considerable variation in their physical structure and condition. Depending on the contents of the inscription, a clay tablet might have been sun dried or kiln fired to preserve it. Unfortunately for modern scholars, sun dried tablets are chemically unstable, and are susceptible to damage from a multitude of sources. Aside from the obvious risk of water or shock damage, some types of clay contain mineral salts that can crystallize on the surface of tablets over many years. If left untreated, these crystals can cause irreparable damage to the acceptable for the purposes of translation, it does not facilitate easy reconstruction of disconnected fragments.

inscribed surfaces of a tablet(Organ, 1961). Even fired tablets are not immune to damage, and special handling procedures are necessary to prevent damage to the fragile artefacts (The British Museum, 2011). The range and quantity of cuneiform tablets collected during the 19^{th} and early 20^{th} century mean that the need for proper referencing and documentation is paramount. Unfortunately, the pioneering scholars of cuneiform studies had limited tools for the recording of finds, and individual scholars familiarity with the collections led to some delay in the creation of detailed catalogues.

At the British Museum, the Kuyunjik collection represents a clear example of the effect of delays in cataloguing. Although excavated in the 1850s, many of the tablets were uncatalogued for several years. It was only the intervention of Samuel Birch, the Keeper of Oriental Antiquities at the British Museum, that lead to the development of a cataloguing system for cuneiform artefacts.

The matter of cataloguing the thousands of items in the department of Oriental Antiquities was not a simple one. Finds from different excavations had been mixed together over time, and there was (at that time)little to distinguish finds from the Kuyunjik mound at Ninneveh with those from other sites (Reade, 1986). Birch was no expert in the translation of Cuneiform text, and despite raising the issue of a catalogue several times, it would be over 30 years before a beginning was made by Birch's replacement (Sir Peter le Page Renouf).

Complete catalogues of the Kuyunjik collection were produced between 1889 and 1896, and provide a 2500 page record of the of 22,220 tablets (Budge, 1925). The tablet descriptions in the Kuyunjik catalogue are detailed, but there are no illustrations of physical shape for the tablets fragments, and only basic measurements of the physical size are included. While this is

Modern recording efforts by the CDLI (Cuneiform Digital Library Initiative) include clear, high resolution colour scans of the Kuyunjik collection, but, like so many other records, the sizing information included with the database is incomplete.

Images frequently lack scale information, and although some sizing information may be included in a catalogue, the units of measurement may be omitted. Furthermore, the measurements given may be the product of human approximation rather than scientific method, and the descriptions in a museum catalogue can be as vague as “approx. 2 inches across”.

A greater understanding of the physical properties of cuneiform tablets is necessary for anyone wishing to facilitate their reconstruction. Without an appropriate template for a complete cuneiform tablet, the process of fragment matching becomes unbounded and difficult to predict.

3D scanning of fragments can provide accurate geometric data that can be manipulated and tested in a virtual environment, but the process of 3D scanning is time consuming.

Since a large number of 2D photographic records are already accessible within the CDLI database, it makes sense to gather as much information as possible from them using the process of photogrammetry.

This paper describes a results of a preliminary scan of over 8000 tablets from the CDLI database, for the purposes of facilitating automatic, semi-automatic, and manual reconstruction as part of the VISTA-CR (Virtual Imaging, Sorting and Transmission Algorithms for Cuneiform Reconstruction) project at the University of Birmingham.

VISTA-CR aims to facilitate the automatic, semi-automatic, and manual reconstruction of cuneiform fragments using collaborative interaction through a web based interface.

2. METHOD

There are three reasons why the CDLI database at UCLA presented a practical resource for automatic photogrammetric analysis:

1) A sufficiently large body of complete tablets were available for study with appropriate copyright attribution.
2) The tablets were for the most part scanned into the computer using a flatbed scanner, not a digital camera on a stand.
3) EXIF data was present in the stored images, and appropriate DPI information could be extracted from the data.

A Python script was used to parse through the records in the CDLI database. The Python language was chosen because it is a modular, cross-platform language, and is easy to program. The python script was able to download, examine, and store images of cuneiform tablets that were candidates for further analysis. Candidacy was determined by the size (pixel-count) of the downloaded images and by the qualities of the image histogram. Files of less than 20 kilobytes, images with a DPI lower than 150, and achromatic (black and white) images were all discarded automatically.

Unfortunately, it was not practical to differentiate between complete tablets or fragments automatically, so manual sorting of source images was employed to separate fragments and remaining invalid images from valid sample data.

The final image set consisting of 8078 samples was passed into another Python script, which scanned each image vertically and horizontally using a simple threshold measure based on the background colour of the image. The largest values from scans in the X and Y axis were used to determine the width and height of the tablet, using the DPI of the scanned image to facilitate the conversion from pixels to millimetres.

The accuracy of the photogrammetric measurement script was tested by direct comparison with known correct data from the CDLI database. In all tested cases, the data was found to be accurate within approximately one millimetre of the recorded values. The resulting data was sorted by period, and analysed using simple statistical methods.

3. RESULTS

After some basic processing, the photogrammetry data reveals that the average size of a cuneiform tablet is 43mm wide by 51mm high. The likelihood that any given tablet from the sample set has a diameter between 23mm and 62mm is over 88%, and a similar range between 25mm and 76mm for the height of a tablet yields a probability of roughly 85%. **Figure 1** shows the distribution of width and height for the X and Y axis.

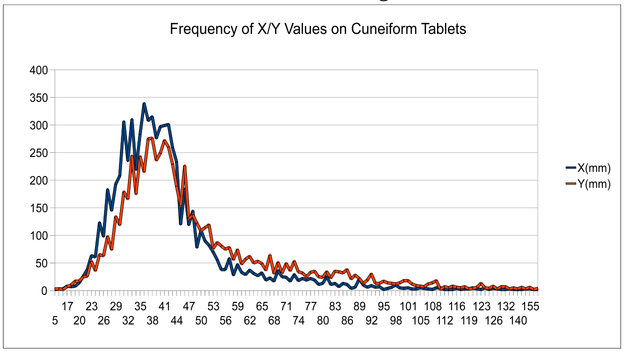

Figure 1: Graph showing the frequency of width and height values (in millimetres) for complete cuneiform tablets

An analysis of ratio between width and height for each tablet has shown that the shape of tablets is far from random. The sample shows a marked bias towards an approximate width to height ratio of 1:1 and a lesser bias towards a golden ratio conjugate of 0.625:1. The graph shown in Fig. 2 illustrates this relationship between width and height.

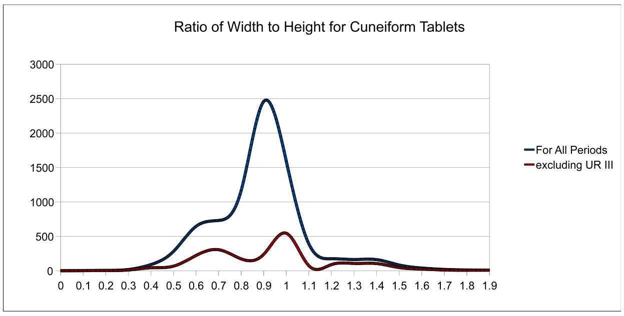

Figure 2: Graph showing the ratio between the width and height of cuneiform tablets.

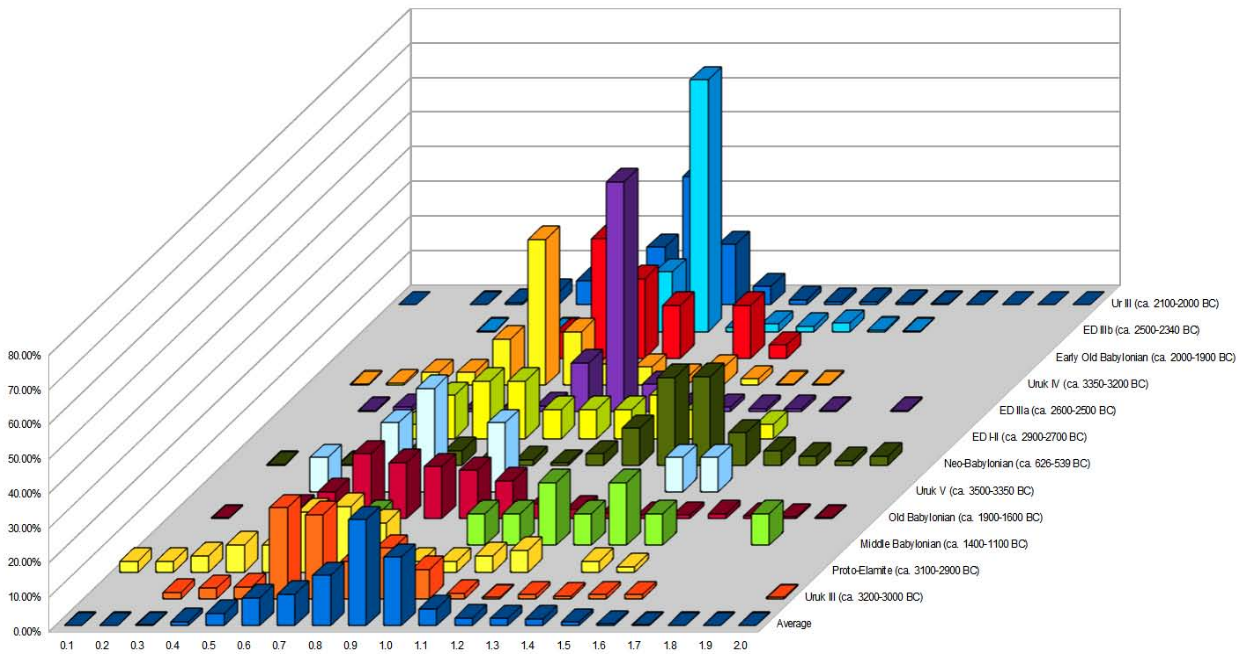

Figure 3: Graph showing the ratio between the width and height of cuneiform tablets separated by period.

It is important to note that a large proportion (approximately) of the analysed tablets are from the period UR-III. In order to ascertain whether the ratio bias was a phenomenon associated primarily with the period UR-III, a separate analysis was made that excluded results from this period. As the graph in **Figure 2** shows, the 1:1 and 0.6:1 trend still seems to be present in the filtered subset of data.

The graph in **Figure 3** provides a deeper analysis of the ratios by era, showing that the range of ratios does seem to cluster around the averages of 0.6:1 and 1:1 depending on the period.

4. DISCUSSION

As has already been stated, the primary motive behind the metric analysis of complete tablets was to provide a basis for further research into fragment reconstruction via the VISTA-CR reconstruction project.

The information presented here does provide statistically significant evidence that the shape and size of complete cuneiform tablets is to some extent predictable, and this provides an important clue for the reconstruction process.

A broad measure of the likelihood of a match between multiple fragments can be predicted by the simple addition of individual fragment sizes. Given the information above, the probability of a match should decrease as the combined fragment sizes deviate from the average size of a complete tablet.

It is also likely that the ratio of width to height can be used in a similar way to reduce the number of possible matches in cases where a complete exterior side is preserved in a tablet fragment.

Although the initial photogrammetry has been performed in 2D, it is hoped that an analysis of fragments in 3D will provide additional scope for matching and presorting metrics. This theory is supported by preliminary investigations using a limited set of 3D models, which have shown that the approximate orientation of a fragment in 3D can be calculated by the simple analysis of a point cloud's absolute minimum bounding box.

The nature of complete cuneiform tablets (and larger fragments) is such that the absolute value of $Z_{(max)} - Z_{(min)}$ will most likely be significantly less than the values for $X_{(max)} - X_{(min)}$ and $Y_{(max)} - Y_{(min)}$. This means that orienting the fragment such that the bounding box Z axis is parallel to the world Z axis should orient larger fragments so that the main inscribed surfaces are near parallel to the X and Y axis.

A customised scanning platform was created to facilitate the acquisition of 3D range and surface data from cuneiform tablets using structured light rather than lasers. Low intensity structured light was used to minimize some of the more difficult problems associated with laser based systems (such as quantum speckle and subsurface scattering) while still allowing for a high level of detail from multiple layers of contrast and phase analysis. An example scan from the new scanning system can be seen in **Figure 4**.

The scanning platform is built around a telescopic photographic copy stand, with a wide aluminium flash bar holding an Acer C10 projector and Canon EOS 600D camera. The camera and projector are connected to a laptop computer using a USB connection. Although designed for structured light scanning, the setup can also be used with a laser wand to generate a conventional laser scan of objects. A ball-jointed camera mount has been added to the top of the copy stand to allow for free mounting of the scanning head. The free range of motion of the head makes it easy to scan in vertical or horizontal configurations.

At the time of publication, the VISTA-CR scanner has been used on a small number of cuneiform fragments and assorted paleolithic objects, but a larger scale scanning effort will begin in late 2012 as part of the ongoing VISTA-CR project.

Figure 4: Sample tablet scan from the customised 3D scanner.

The accuracy of the VISTA-CR scanner depends on a number of factors, including the hardware used and the size of the object being scanned. The specifications of the camera and the projector most important, since the resolution of these devices will determine the maximum number of points that the scanner can sample in one scanning pass. If the maximum size of a scanned object is 1000mm square, then the maximum resolution of the scan using an 800x600 webcam and projector will in theory be (800*600)/1000, or 480 samples per mm. In practice however, this resolution would probably be lower, as it is unlikely that the projector and camera could be calibrated perfectly together.

The scanning process is fast (usually under 30 seconds per scan), and multiple scans of a surface can be taken in under one minute. A complete cuneiform fragment can be fused together from 8 scans in approximately 10 minutes, and then exported in a format that the VISTA-CR system can process.

Practical experimentation with the system has shown that the principal disadvantage of the structured light scanning process is a sensitivity to incidental light. The intensity of structured light projections is much lower than laser line projectors, and environmental lights will reduce the ability of the scanner to capture clean data. For this reason, scanning is carried out in a light controlled environment, away from direct sunlight.

5. FUTURE WORK

Following on from the process of orientation by bounding box, the pre-orientation of tablet fragments using the cuneiform markings as a reference point may provide a significant speed boost to the assisted and automatic fragment matching process.

Since text direction will be consistent across the surface of a cuneiform tablet, it is reasonable to presume that orientation based on text direction will provide a uniform starting position for many matching algorithms.

The popularity of OCR software has ensured that a number of language independent methods exist for the orientation of written data (Hochberg, 1995; Lu, 2006), and it is probable that these can be adapted to suit the cuneiform text found on the tablets. The characters themselves can be retrieved using a relatively simple thresholding filter that can create a 2D map of the rate of change of height across the surface of the tablet. This method of surface feature detection has been used successfully in Stanford's Forma Urbis Romae project. (Koller, 2006; Koller, 2004; Laugerotte, 2004)

The identification of 'good' and 'bad' edges or surfaces could also lead to a radical reduction in the amount of data that needs to be processed during the reconstruction process. If we assume that an intact, undamaged edge or surface on a tablet is 'good' and a broken edge is 'bad', we can discard (or at least severely reduce the importance of) those 'good' edges from the matching process.

A 'bad' edge will always connect with another 'bad' edge, and the relative positions of the 'good' edges can be examined to improve the certainty of a match. Detection of these 'bad' edges may not be difficult. Physical markers like asymmetry should provide a strong marker broken edge, and such asymmetry be detected quite easily. Analysis of the fractal dimension (Wong, 2005) of an edge might also provide a useful method for detecting 'good' and 'bad' edges. It may even be possible to use the fractal index of a 'bad' edge to generate potential fragment matches by modifying the techniques exploited by Papaioannou & Karabassi (Papaioannou, 2002), although this will need to be tested experimentally.

A simple count of the number of surfaces that have markings can also be used to reduce the number of cycles required to generate a match. If a tablet has markings on both sides, and has been chosen as a potential match based on it's physical dimensions, it may be that a simple 180 degree rotation around the match surface could make the difference between a good or bad match. This scenario is most likely in the case of a shear break that runs across a tablet, nearly perpendicular to the 'good' edge of the tablet.

Further pre-processing of data can be used to generate a list of the angles for all corners of a tablet fragment. These low volume lists of angles could be searched quickly to identify potential matches (Onsjo, 2009; Schatz, 2007), or used to generate simple polygon models as shown by Konoh and Kato(Masayoshi, 2001-06).

The manual and automatic processing of fragments will take place on the VISTA-CR server. VISTA-CR is a 2D and 3D reconstruction framework that aims to provide a robust system for the automatic, semi-automatic, and manual reconstruction of cuneiform tablets. The framework is designed to use techniques taken from complexity science (specifically emergence and stigmergy) to facilitate the interaction of multiple concurrent, pattern, edge, and surface matching algorithms in a distributed and collaborative way.

Figure 5: The VISTA-CR 3D web interface.

The web based VISTA-CR interface (shown in **figure 5**) has been created to facilitate human interaction with cuneiform fragments online. The interface is designed to run on the Google Chrome platform, under Windows, Linux, and Apple Mac computers with an appropriate pointing device. The display currently supports 2D and 3D monitors with shutter or passive glasses, and future development will improve the interface of the system for multi-touch devices.

Although the hardware requirements for visualisation are higher than most websites, the interface performs as expected on a computer or laptop of moderate power, with a normal connection to the internet. Data transactions are minimized by local caching, and further improvements will be made to increase performance in this area as the project advances.

6. CONCLUSIONS

We have shown that there are areas of predictability within the size of cuneiform tablets, and explained how these predictable features can be exploited to improve the speed and accuracy of suggested matches between cuneiform fragments in the VISTA-CR system.

By implementing these different algorithms as agents within a framework for stigmergic collaboration(Elliott, 2007), it is hoped that fast, accurate methods for distributed cooperative reconstruction of cuneiform and other archaeological fragments can be developed to assist the digital heritage community.

7. ACKNOWLEDGEMENTS

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A COMPLETE MORPHOLOGICAL STUDY OF THE RIGHT HAND OF BRONZO "A" DI RIACE

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KEY WORDS: Reverse Engineering, Riace Bronzes

ABSTRACT:

The Riace Bronzes represent one of the most important masterpieces of Magna Graecia archaeology, and of the whole world artistic heritage. The Bronzes, other than for their exquisite workmanship, are also interesting for the mysteries which surround their history. The countless hypotheses about their identity, origin and authors are supported by many studies of historical and iconographic nature. This paper describes a complete morphological study of the Riace Bronzes in order to provide to the archaeologists some objective data about the shape of the most interesting and controversial part of the Bronzes: the right hand of Bronzo "A". This study aims to provide a series of geometrical data which could help to identify the object that the A Bronze was gripping. This questions is, in fact, one of the fundamental steps for the individuation of the Bronze A's identity.

1. INTRODUCTION

In literature there are several examples of digitization of two-dimensional paintings and 3D objects of different materials, including wood, stone, marble, pottery and metals (Marc, 2000, Bernardini, 2002, Beraldin, 1999, Schindler, 2003). In the field of 3D scanning for cultural heritage there is a vast literature reporting studies and analyses based on different techniques and applied to different kinds of finds. Several papers are focused on the reconstruction of artefacts starting from a set of fragments. Some researchers approach the problem by searching for the best matching between the edge boundaries of the single fragments, while others adopt specific approaches to deal the problem more efficiently (Leitão, 2000, Üçoluk, 1999, Papaioannou, 2003, Kampel, 2003, Willis, 2003, Halíř, 1999, De Napoli, 2002).
Virtual reconstruction has also been applied in the archaeological field to recreate the look of historic figures (Wilkinson, 2003) and mummies (Cesarani, 2004, Gill-Robinson, 2006). Combination of non-invasive technologies like 3D laser and tomographic scanners is used in paleoanthropology for 3D reconstruction of craniums (Zollikofer, 2005), of broken bones and missing fragments (Ruff, 2007a). Recently, some experiments in estimating and predicting the height and the body mass of an adult individual starting from juvenile bone fragments have been conducted (Ruff, 2007b). In (Grün, 2004), the authors describe the reconstruction of the Great Buddha, which can constitute the basis for a physical reconstruction of the colossal statues demolished by the Taliban government militia.
In the work of (Granero, 2009), a structured light scanner has been used to reconstruct a fragment of a bronze sculpture to perform an anthropomorphic study of the hand and arm giving as a result their position respect to the whole statue. In (Dellepiane, 2007) a laser scanner in conjunction to image-to-3D-model mapping techniques, has been used to evaluate the plausibility of an attribution hypothesis of a Renaissance artefact, a small bronze horse, which was discovered to be very similar to a silverpoint drawing by Leonardo.

This paper describes the reconstruction procedure and the analyses performed on the 3D model of the right hand of one of the two Riace Bronzes, housed by the *Museo Nazionale della Magna Grecia* in Reggio Calabria (Italy).
Riace Bronzes (Figure 1) are statues of incomparable workmanship and highly refined taste; that can be historically set in the early classical age. However it is not yet certain who was the author (or the authors) of these masterpieces. Is the author one of the famous Greek artists, Phidias, Polykleitus or Myron? Or is he an anonymous sculptor working in Magna Graecia? He was certainly a highly skilled craftsman and a sensitive artist, who almost surely lived in the 5th century BC. On the other hand, it remains a mystery also whom the two statues represent. They may be Castor and Pollux or they may depict Harmodios and Aristogeiton; or, more simply, they portray two warriors, armed of a spear and a shield, hoplites with a bold look, a proud expression and a Greek profile.

Figure 1: Riace Bronzes.

* Corresponding author.

This paper, after drawing a brief historical frame, describes the acquisition procedure, carried out by 3D scanner, and the subsequent 3-dimensional reconstruction. The model thus obtained has been used to define quantitatively the shape and the size of the cavity within the right hand of the "A" Bronze, also termed the young. The gathered information can give useful indications on the typology of the object grasped by the statue and lost since long.

2. WHO ARE THE RIACE BRONZES?

According to Moreno (Moreno, 1998), the "A" bronze, the young, might represent Tydeus, a hero of greek mythology, the son of Oineus, king of Calydon, and of his daughter Gorge (or perhaps of his second wife Periboea). The trace followed by Moreno is a "baedeker", describing towns and monuments of ancient Greece, written by Pausania in the second century AD. Pausania reported that in the Polis of Argo there was a monument dedicated to the "Seven against Thebes". The monumental group was composed of about fifteen statues, carrying shields, swords, spears and elms; they, according to Moreno, included the Riace Bronzes. Stucchi (Stucchi, 1998) hypothesizes that the "A" Bronze could depict Euthymos from Locri, represented as the winner of Temesa. Stucchi believes that the statue is the work of the great sculptor Pythagoras from Rhegion. According to Paribeni (Paribeni, 1994), the "A" Bronze might portrait a hero, perhaps Ajax the Lesser, son of Oileus, and he claims the author be a Peloponnesian artist. Paribeni draws these conclusions from the craftsmanship of the "A" Bronze, which is , in his opinion, clearly non Attic. The researcher agrees with the theory that there is a noticeable chronological distance between the "A" and the "B" Bronze, believing the "A" Bronze to be a work pertaining to the severe style and the "B" one to the later classical style of the last part of the century. According to recent studies (Roma, 2009), the bronzes could depict Castor and Pollux; the statues weren't on the seabed as a consequence of a shipwreck, but they were buried intentionally. Every year, in the second Sunday of May, the population of Riace walks in procession to the cliff where the statues have been found: the relics of Saints Cosmas and Damian, the patron saints of the town, are immersed in water. Giuseppe Roma claims that this tradition is a typical example of continuity between paganism and Christianity. He mentions also that, as demonstrated by Stanley, some centuries ago the shoreline could have been some 400-500 meters wider of the current one. If one considers also that no traces of a ship have ever been found in the area where the Bronzes have been discovered, one could assume that the statues were buried in ancient times.

3. WHAT WAS THE "A" BRONZE HOLDING IN HIS RIGHT HAND?

The simple visual analysis of the statues allows only some general observations. The most common assumption is that each of the two statues lost three objects: an elm, a shield, a spear. On the basis of this assumption, Figure 2 shows two quite similar possible representations of the "A" Bronze incorporating the three missing elements. Where the object hold by the "A" Bronze in his right hand is concerned, four regions can be evidenced where the hand shape differs significantly from the anatomic shape; these "excavated" zones can be considered particularly relevant with reference to the object possibly clutched. The four areas are located in the proximity of the abductor pollicis brevis muscle, of the little finger, the ring finger and the middle finger (Figure 3).

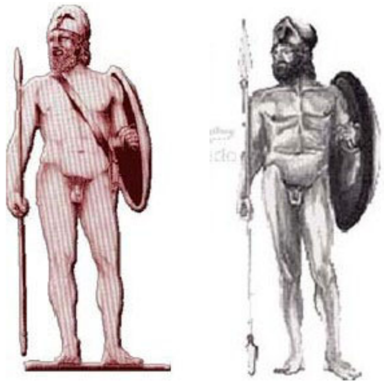

Figure 2: Reconstruction of the missing parts of the "A" Bronze.

Figure 3: Details of the hand of the "A" Bronze.

The "A" Bronze seizes the missing object in a particular way. With the right hand stretched out, on his back on the horizontal plane, he flexes his fingers, adducts the index finger and inserts the missing element between the index and the middle finger, while the other fingers grip and wrap the object.

This way of gripping an object, if it could be unusual nowadays, seems instead to be quite common in Roman and Greek paintings and sculptures. Many of these representations, in fact, show warriors or famous persons in the act of holding lances, scepters or staffs with this particular modality (Figure 4).

All the hypotheses present in literature are supported by iconographic studies and/or historical sources. This research wants instead to provide to the scholars a series of objective confirmations on geometrical data, which are not easily measurable on the statues in a direct way. So we want to make 3D scanning techniques and geometrical analysis available for reconstructing and analyzing the most interesting anatomical parts, which could provide objective data for the study about the identity of the depicted characters.

Figure 4: Paintings with various handles of spears.

The first analysis that has been carried out has concerned the shape of the Bronze A’s right hand, as this presents some tissue deformations which could represent a good starting point for the analysis the hand posture and the elaboration of hypotheses about the objects which could have been gripped.

4. THE METHODOLOGY FOR THE RECONSTRUCTION

In order to acquire the Bronze’s hand, we have used a structured light scanner, that are also well-renowned and widespread in 3D reverse engineering. Special structured light beams, that produce straight horizontal and vertical lines, are projected on the object. Following the principle of photogrammetry, two images taken by two different cameras are interpolated and the result is a dense point cloud. The scanner used in this process was a laser structured light scanner produced by *Scansystems S.r.l.*

The main obstacle which we met in this study is related to the fact that the hand, being closed as to grip something and placed near the hip, presents some hardly accessible areas. This happens because the scanner needs to observe a point simultaneously with both cameras in order to acquire it. The hand has been acquired from various positions, in order to achieve a full shape of the object that can include also the internal part of hand (Figure 5). With the use of multiple scanning positions we were able to cover around 95 % of the hand limiting the missing parts - reconstructed by interpolation - to only a 5 %: This allows us to affirm that the fidelity of the reconstructed model is adequate to carry out quantitative analyses on it. In total, we carried out 25 scanning processes, obtaining 2.473.171 points.

The subsequent triangulation between the points and the effective division in polygons is executed by 3D modelling software tools. The proprietary *Scanprobe* software has been used for 3D acquisition and patches registration. The same software has been employed for noise reduction and triangulation. Fine retouches and missing parts reconstruction have been done with *Meshlab*. After this phase, the final number of points was 191.952. Finally, using a 3D painting software, the CAD model was finished with the texture (Figure 6).

Figure 5: The acquisition procedure.

Figure 6: Cloud of points, polygonal and textured model of the right hand.

5. MODEL ANALYSIS

Once obtained the virtual model of the hand, we were able to carry out a series of analysis, aiming to determine shape and dimensions of the internal cavity of the right hand of the A Bronze. First of all, showing the 3D model of the hand to archaeologists, they were able to appreciate the possibility of a free rotation of the object, allowing them to observe the object from angles that, due to the proximity of the hand with the body, would have been impossible to visualize. In particular, the hand is contained in a 182x101x105mm box. The first analysis concerned a part of the middle finger which presents an evident flattening: its profile looks like a circular arc. In proximity of this flattening we defined the maximum inscribable cylinder, and on the base of its axis we realized 14 sections, spaced of 10 mm. This subdivision has allowed to determine the maximum inscribed circumferences in each section, as well as the internal volume (Figure 7).

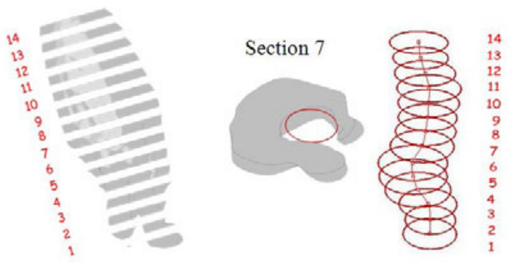

Figure 7: Subdivision of the hand in 14 sections

In table 1, the 14 diameters related to the circumferences obtained in every section are shown.

Sections	**1**	**2**	**3**	**4**	**5**
Diameter max (mm)	33.8	31.6	36.1	41.1	41.6
Sections	**6**	**7**	**8**	**9**	**10**
Diameter max (mm)	42.8	38.3	37.1	34.6	36.1
Sections	**11**	**12**	**13**	**14**	
Diameter max (mm)	37.9	35.3	32.3	32.8	

Table 1. Diameters of circles inscribed into the hand.

In relation to the 4 hand sections, in which the palm deformation deviates from the anatomical configuration, i.e. an evident tissue flattening is present, the corresponding diameters are, respectively:

1) 33,8 mm - section corresponding to the middle finger (section n° 1).
2) 38,3 mm – section corresponding to the ring finger (section n° 7);
3) 36,1 mm – section corresponding to the little finger (section n° 10);
4) 32,3 mm – section corresponding to the *abductor pollicis brevis* (section n° 13).

Assuming the hypothesis of the presence of a spear in the right hand of the A Bronze, it is possible to state that there is a cylindrical element, with an about 30 mm maximum diameter, which is always contained inside the volume defined by the 14 circumferences. This element is adjacent to the points of the hand corresponding to the deformations that deviate from the natural anatomical configuration (circles 1-7-10-13 of Figure 8). Figure 9 shows these sections, the maximum inscribed circumferences and the relative position of the cylinder.
Obviously, it is always possible to hypothesize the presence of an object, with a non-rectilinear axis or with a non-cylindrical shape, contained inside the volume of the palm of the hand. Figure 10 shows two possible reconstructions. In Figure 10-a, the most likely reconstruction of a spear, 2 m long with a 30 mm diameter, is shown; Figure 10-b shows an unlikely solution (Roma, 2009): the bronze holding the rein of a horse.

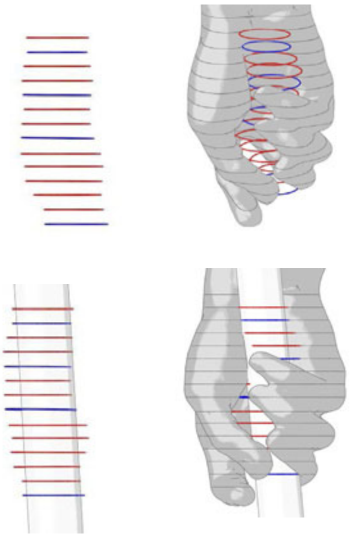

Figure 8: Maximum inscribed cylinder contained inside the volume defined by the 14 circumferences and adjacent to sections 1-7-10-13.

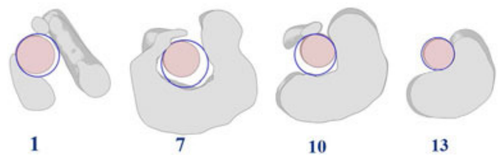

Figure 9: Details of the sections 1-7-10-13 with the inscribed cylinder of 30mm of diameter.

6. CONCLUSIONS

In this paper, we have described the reconstruction procedure and the analyses performed on the 3D model of the right hand of one of the two Riace Bronzes, housed by the *Museo Nazionale della Magna Grecia* in Reggio Calabria (Italy). In particular, this study has provided a series of geometrical data useful to identify the object that the A Bronze was gripping. Without entering into merits about the individuation of the Bronze A's identity, we can assume which is very likely that the Bronze held a spear of 30mm and a length of about 2200mm.
This experience has confirmed that the morphological study using virtual 3D models can be considered an effective tool to validate both formal and historical/scientific assumptions.
Although this work did not bring immediate profits at the Museo Nazionale della Magna Grecia in Reggio Calabria, the data collected (in VRML format) constitute an efficient repository and an useful database for future study or for any restoration work.

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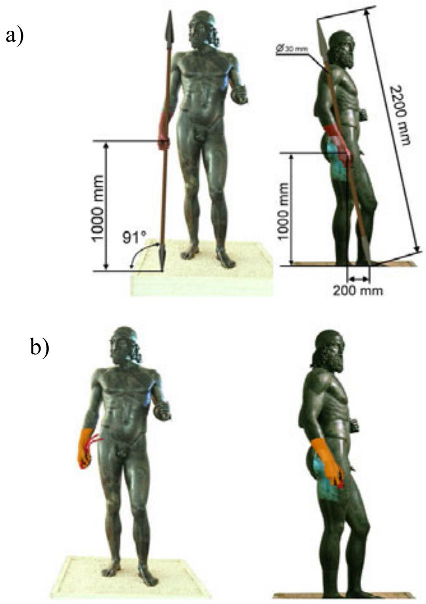

Figure 10: The two different hypothesis: (a) a spear; (b) a rein of a horse.

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Neolithic settlement in Bylany: taking a new look at old digs

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KEY WORDS: Virtual museum, Archaeology, Neolithic settlement, Bylany (Czech Republic), Pottery, Lithics, GIS, 3D optical scanning

ABSTRACT:

The aim of the project is to apply 3D scanning technology to create a virtual museum providing a picture of the Neolithic culture, based on the example of the settlement in Bylany (Czech Republic), dating from the 6th – 5th millennium B.C. The main parameter of the applied research is to set up a methodology for recording and presenting archaeological finds digitally. The basic technology is optical 3D scanning of artefacts that exactly reflect the 3D surface geometry and will bring new presentation possibilities. Acquired digital records can also serve as well as for research and educational purposes on all academic levels. The project's most important output consists in a virtual museum on the web of the Neolithic settlement area. Moreover, the open library of 3D scans will integrate a thematic GIS map of the Bylany site and its virtual model showing different forms of the immovable heritage (i.e., houses, circle enclosures and villages).

1. INTRODUCTION

The given issues of 3D imaging and virtual modelling of monuments, especially movable ones, can be considered on two levels. The first is the field of making the cultural heritage more accessible and popular in which the method of 3D visualisation is used to make the presentations more attractive (Bruno et al., 2010). This also happens within exhibitions in traditional museums. Nevertheless, Internet exhibitions are the home ground of virtual 3D visualisation and recently these exhibitions have been spreading very rapidly and becoming an inseparable part of museums and other cultural institutions (Grant et al., 2008).

The other level using 3D projection techniques is the effort to perform the shape analyses of an object through the parameters of its virtual model. These methods of scanning and imaging have great analytical potential especially in those fields which are based on material sources. Three-dimensional scanning and geometric morphometrics already are a part of the standard portfolio of methods used in disciplines related to archaeology, such as anthropology (physical and paleoanthropology) (Urbanová and Králík, 2009). Archaeology itself is a field, where laboratory scanning and consequent analysis of data are just beginning, as documented by the published data of focused works (e. g., Saragusti et al., 2005; Archer and Braun, 2010; Bruno et al., 2010).

The objectives of these analyses usually focus on the unbiased assessment of the shape parameters of artefacts based on the image and statistical data extracted from polygonal models. Such approaches are collectively called geometrical morphometry. The published examples show that not only the issues of artefact typology and chronology, formal variability of style and technological varieties, but also functions of the studied objects can be solved in this way. The methods of 3D scanning and modern morphometry can be applied to the whole variety of artefacts from ceramics (Gilboa et al., 2004; Saragusti et al., 2005) to chipped stones (Archer and Braun 2010; Buchanan and Collard 2010; Lycett et al. 2010). A brand new trend within virtual 3D visualization is sharing databases of models of artefacts on the Internet. The access and potential for studying virtual models thus often replace the direct manipulation with archaeological findings, which are often difficult to reach. This significantly contributes to the process of learning about the past and also improves the prospects for the protection of these objects as such.

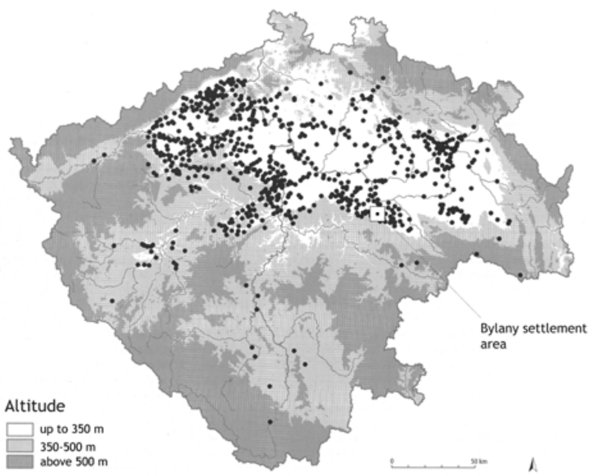

Figure 1: Bylany location map within Early Neolithic (LBK) settlement area in Bohemia

1.1. Bylany settlement

The aim of the project was to use the technology of 3D scanning to create a virtual museum which would present the picture of Neolithic culture in our territory as an example of a large settlement in Bylany near Kutná Hora. This locality is of global importance and the information provided by a long-term research on the spot, in fact, is basic knowledge about the world where the first farmers lived in Central Europe (Figure 1). The field project in Bylany was begun in 1953 and its goal was to completely excavate the settlement area from the Early Neolithic period (5500 – 5000 BC, Linear Pottery culture or LBK). During a period of 15 years, a total of seven ha (70,000 m , which is approximately seven football fields) was excavated, dating to the Early but also subsequent periods of the Neolithic. A total of 1,045 archaeological features and 144 more or less reasonably preserved ground plans of long houses were also studied. Archaeological finds make up a large assemblage of artefacts that includes pottery fragments, chipped stone, polished stone (axes and adzes), whetstones (abrading, smoothing, polishing tools), manos and metates (grinding slabs and querns). The most significant in terms of the chronology is the assemblage of pottery finds containing more than 76,000 fragments. In light of the fact that the archaeological monuments from this locality are not and have never been accessible to the public, this virtual exhibition will be the first complete presentation of the collection.

2. METHOD

The specific purpose of the project is the creation of a methodology for registration, preservation and presentation of archaeological findings in a digital form. The basic technology is optical 3D scanning of artefacts whose advantage is the ability to capture an absolutely faithful three-dimensional model of an object. This creates new barrier-free options for the presentation of both movable and immovable finds and also multiplies the potential of their presentation in case the original is destroyed. In the light of recent global experience this, unfortunately, is quite a real danger. (For example, The National Museum of Iraq destroyed by war in 2003 and the centres of cities in Central Europe hit by catastrophic floods in 2002.) Methodologically, the project will be realised on three levels:
a) The creation of a digitising laboratory, where the originals of archaeological finds will be transferred into a digital form. This will be realised by a 3D optical scanner Breuckmann SmartScan 3D-duo with accessories and corresponding software equipment. A web database will be created to secure the optimal course of work and individual models will be put into this database. At the same time a SW interface will be developed to run an online accessible 3D archaeological virtual museum with a wide range for users´ choice of views and options of virtual manipulation with the object.
b) To make the presentation more illustrative, the museum will include specialised maps in GIS format, which will be made on the basis of field documentation of research. All the data will be publishable on the Internet through the specialised software of the Esri-Arc GIS Server 10 Workgroup, which will require no specific installations by the user/visitor to the museum.
c) At the same time, 3D virtual reconstruction of the Neolithic settlement and chosen structures (such as long houses and circle enclosures) will be created. These targets will be met through specialised software, which will enable rebuilding the original shape of the countryside on the basis of preserved field situations. This will provide a picture of a lively socio-cultural landscape. The final image will also be presented in site on several transparent boards which provide an observer with a precise picture of what the settlements of the area's first farmers actually looked like.
So-called "cloud computing" is intended as the final methodological solution for the web museum. This is a very progressive method of storage and making access to specific digital data, which are located in the data centre on the server and can be used through common web browsers. No installation of specialised licensed programmes by the end users is required.

2.1. Acquisition of 3D models of artefacts.

The method of choice is the acquisition of shape and colour information by optical scanning and using the scanner smart SCAN-3D (Breuckmann, GmbH). This modular topometric system works on the basis of a fringe projection of sequences of stripes on a physical model and recording the modified samples with a digital camera with high definition (5 MPx). Individual scans depicting the surface of the object from various points of view are subsequently merged into a final data object which defines both complex geometry and the texture of the scanned artefact. High accuracy of scanning artefacts (which are variable in terms of size) is made possible by the use of three additional measuring ranges for three fields of view from 60 to 300 mms (FOV S060, FOV M125, FOV M300). The system includes programme equipment (OPTOCAT SW) which ensures the service of the digitising system during the process of scanning, automatic merging of individual scans and export of scans to various data formats. Another fractional task is the reducing the size of the file into a small fraction of its original size for the purposes of the web presentation. That means the objects which have not been displayed yet will be opened up to all interested people, including specialists. Specialists will be able to download polygonal models in their original (high) definition and consequently analyse them with any conventional methods including progressive approaches of geometric morphometry (Figure 2).

Figure 2: 3D optical scan of LBK vessel.

2.2. Presentation of 3D models.

Final 3D models will be published on the web through the RDV Civil 3D programme and a built-in visualising plug-in directly in the web browser and it will be unnecessary for users to install other software. The virtual museum will be activated on the already existing and established domain, www.bylany.com. The graphic environment of this page will be transformed for the needs of the presentation of 3D models and interactive browsing.

2.3. GIS reconstruction map.

The original map documentation of the archaeological excavations in Bylany was converted into a vector digital form. The resulting data is saved in a SHP format with the setup of geographical coordinates for the national grid S-JTSK (east-north). The SHP format is primarily intended for GIS software by the Esri Company, but can also be regularly used in other GIS programmes. The GIS system covers the complete area of the Bylany project and its individual components are adjoined both to the original documentation of field research and to the archaeological interpretation (Figure 3). Just this level of the reconstruction will become a part of the virtual museum. The relationship of various immovable monuments (houses, sacral circle enclosures or the development of the settlement) to each other and to the environment will be made clear in this form. While the current map of the Neolithic settlement in Bylany, realised in the ArcGIS environment, works regularly in 2D, the new virtual version will be three-dimensional. Therefore, a system based on Esri – ArcGIS Server 10 Workgroup level platform will have to be created, which will interactively cooperate at the same time with Autodesk and Google

SketchUp formats. The final system should facilitate the complex web administration of GIS, data, editing maps and be an easy way to publish maps on the Internet. The given programme will be included in the web museum and work as an interactive browser.

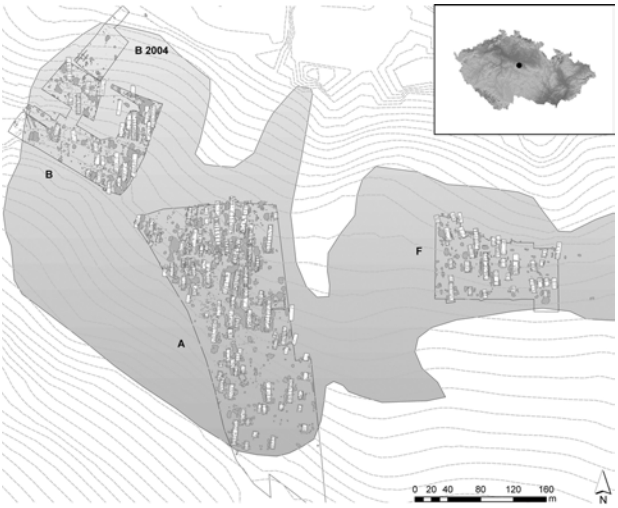

Figure 3: The status of archaeological excavations of the Bylany 1 area. The grey area indicates the total area of 21 ha inhabited during the Early Neolithic period.

2.4. Visualisation of 3D situational reconstructions of archaeological features.

The map part will also include a virtual tour around the Neolithic landscape. It will be based on the digital documentation of the geo-relief and archaeological findings included in the 3D GIS project and, moreover, it will add reconstructions to the map. These will have the form of real models (objects built on the basis of archaeological records and factual reconstruction, Figure 4) and computer views (a kind of scenic reconstruction, Figure 5). The reconstructions will be created also with the software package Autodesk and Google SketchUp. The result will be not only static images, but also dynamic presentations accessible either in the form of interactive cooperation user-application or animation with narrative attributes.

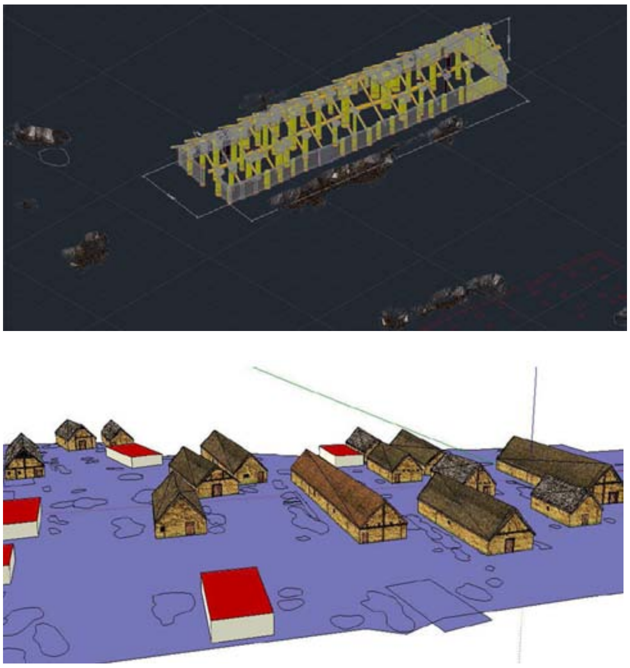

Figure 4: Samples of various types of 3D reconstructions (Authors: P. Vavre ka, . Kravciv).

3. DISCUSSION/CONCLUSION/FUTURE WORK

The default solution will be the project which was completed in 2007 called “Neolithic settlement in Bylany – essential database”. The documentation of the results of the archaeological research in Bylany was transformed into the form of a compact line-up which includes database, image documentation and a GIS map. It was published as a whole both in the printed form as a digital part of a metadata handbook and on the Internet in the domain, www.bylany.com. (Kv tina and Pavl , 2007). The current project is advancing in accordance with a time schedule and with the digitising laboratory work having started earlier this year, to date, 250 artefacts (70 of them are vessels) have been scanned. During the following years (2013-2015), we assume the creation of optimised database of 3D models of artefacts of the following categories: complete ceramic vessels (at least 200 pieces), ceramic fragments (at least 300 pieces), polished stones (at least 500 pieces), chipped stones (at least 500 pieces) and grinding stones (at least 50 pieces). At the same time the corresponding software default for depositing and inspection of 3D models of artefacts will be created as well as a special GIS map for the Internet application.

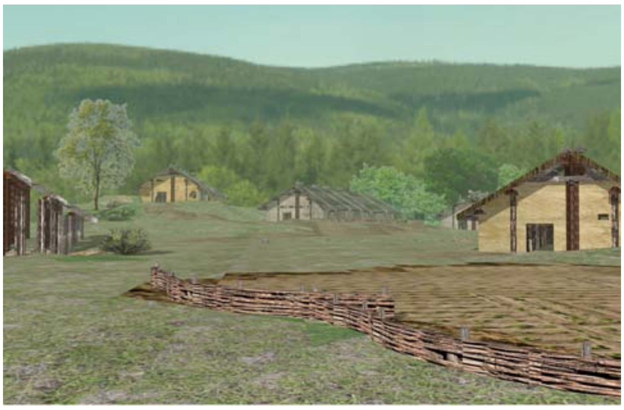

Figure 5: Sample of scenic reconstruction of a Neolithic settlement. (Author: P. Vavre ka).

ACKNOWLEDGEMENTS

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HOW DOES DIGITAL PROGRAMS HELP TO UNDERSTAND URBAN EVOLUTION THE STUDY CASE OF A PORTUGUESE MEDITERRANEAN VILLAGE

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KEY WORDS: Mediterranean Architecture, Urban History, Urban Morphology, Visual and Spatial Network Analysis, Depthmap Software, Town of Fuseta

ABSTRACT:

The cultural heritage of the fisherman's town of Fuseta, on the southern Portugal, is an interesting example of Mediterranean vernacular architecture. Totally built in just one-step at the turn and the 19th to 20th centuries, the historic centre presents a homogeneous urban fabric characterized by a typology of house covered by vaults' terraces, and pyramidal roofs, strategically located. Nowadays, the urban network extrapolates the original historic centre to the involving areas, with a demarcated rural structure.
This paper aims to reflect on the contribution of space syntax descriptive model, an alpha numeric's calculation software (Depthmap Software), based on visual and spatial networks' analysis, to the study of the urban evolution.
The almost non-existence of bibliography related to the urban history of this territory, enforces the use of alternative methods to increase the architectural morphology's theories and other theoretical approaches focused on the reading of urban territories.
The Depthmap modelling of the town's digital cartographics allowed the production of maps that expresses parameters and urban concepts universally defined. The main question consists in how deep this new urban modelling information is and how useful are these maps or they just descriptive.
In conclusion, the appliance of the Depthmap Software on the study of the Fuseta's urbanism made it possible to draw a reliable parallel between the unknown urban characteristics of the 20th century beginning with the well-known structure of today, at same level of measurements, detailing, information and parameterization.

1. INTRODUCTION

1.1 The Mediterranean Town of Fuseta

Fuseta is a fisherman's town in Algarve, the southern region of Portugal. It was built between the 19th and the middle of 20th century (although the first settlements go back to 16th century), and like other villages on Algarve's coast, has Mediterranean characteristics. The homogeneous urban fabric of the historical centre is characterized by a typology of house covered by vaults', terraces, and pyramidal roofs, strategically placed, both with an important bioclimatic performance. The main aspects are still maintained due to its geographical location bounded by a lagoon, a river and a railway, preserving it from deep changes.

Figure 1: Actual aerial view of Fuseta's town. (Image ©2012 Google Aerodata International Surveys Cnes/Spot Image. Digital Globe, GeoEye, IGP/DGRF)

1.2 The challenge of Fuseta's urban evolution

The application of space syntax descriptive model software (Depthmap Software) to study the urban evolution of the town is connected with the problem of the lack of primary sources', which are necessary to know the morphologic characteristics of the territory in the past and compare it with the present urbanism, establishing the same kind of approach and evaluation. Therefore, the aim of using Depthmap Software is to generate a group of digital information of Fuseta, both about the past and the present network, which will make possible to compare these different periods and determine the urban evolution, with these new sources.

The new information provided by Depthmap Software brings a different type of reading of the territory, which is indispensable to develop and inquire into the studies done by other authors in the fields of urbanism, architecture, anthropology and sociology. As important examples of those researches, it should be mentioned the work produced by the team of the Inventory of Vernacular Architecture in Portugal during the 50's of last century (Martins et al., 2004), publishing the first urban plan and architectural details of Fuseta's houses' typology; the anthropological approach to the village's population (Ramos de Oliveira, 1971), describing the existence of Seamen and Landsmen's groups and neighbourhoods, according with their economical activities; and recently, the study about the urban and architectonic evolution of the village (Pacheco, 2009), which propose an empiric interpretation based on urbanism concepts to define the evolution network model, can now be deeply revised.

2. MODELLING THE EVOLUTION OF URBAN MORPHOLOGY

2.1 From orthogonal old town structure to the new organic streets

To understand the evolution of Fuseta urban morphology it was necessary to consider a time interval of a century (from 1900 to approximately 2010), which mean comparing the morphological conditions since its beginning (when the provisory wooden houses were substituted for masonry houses) with modern construction. This comparison will inform how the urban expansion changed the old town's structure, namely how the orthogonal plan was affected with the extension of the main streets and planning of new ones, over the adjacent lagoon area.

The old town is composed by an orthogonal urban fabric with long axes of northeast - southwest orientation, with parallel streets crossed by perpendicular axes, adapted to the differences of topography, sun exposition, winds and waves direction. Concerning the urban fabric extension during the last decades, the most important action consists on the east riverside new waterfront street and the new urban areas at south, with an organic delineation because its confinement to the riverside and the lagoon, contrasting with the old town.

2.2 Methodological procedures

To compare the old urban core with the new urban area, three different models were developed: 1) the urban core at the beginning of the 20th century, 2) the urban core in the 21st century and 3) the current town's area. This urban analysis was followed by a local scale analysis, where the main squares were compared in both periods.

Figure 2: Main street with northeast - southwest orientation on the beginning of 20th century and on the 21st, on the left side, and the river front on the 20th century, on the right side.

Starting with a 2D digital cartography in a CAD format model of the actual village's urban fabric, the urban fabric was reconstructed as it should be during the beginning of the 20th century. Although the urban core has the same plan, the surrounding streets did not exist on that time. This reconstruction was developed according with the map published on the Inventory of Vernacular Architecture in Portugal, during the 50's of last century (Martins et al., 2004) and photos taken by the population during the same period.
Both cartographic modelings (of 20th and 21st centuries) in a 2D vector drawing format were simplified in the way that each street is represented by a line or lines with the longest possible, and squares transformed in crossed lines. The success of this proceeding depends of the knowledge that author has of the place. The lines' set, represented in the same layer, were imported to the alpha numeric's calculation software (UCL Depthmap Software), originating Depthmap graph files.

The Depthmap Software, a space syntax descriptive model based on visual and spatial networks' analysis, generate sets of two kinds of maps: a) axial maps, which analyzes concepts like connectivity, integration, synergy, intelligibility, entropy and b) visibility maps, which evaluates the step depth's parameter, which mean the shortest path from a chosen point of the system, in this study the main squares, among other parameters in both type of maps.

2.3 The axial maps

Importing the 2D-CAD format of the axial map (composed by lines which correspond to the urban plan) to the Depthmap Software, an automatic graph is generated with connectivity's measures. The graph is also used to calculate other syntactic measures by running different analysis' parameters.

2.3.1 Connectivity and segments' number

The axial map of connectivity describes the number of lines that each axe intersects with. From the 20th century to 21st, the connectivity increased slightly, around 113 percent. However, comparing the urban core with actual village's area, connectivity decreased more than 69 percent. Regarding to the segments' number of each model, in a range of a century, the urban core increased 177 percent, and the urban area increased up to 400 percent.

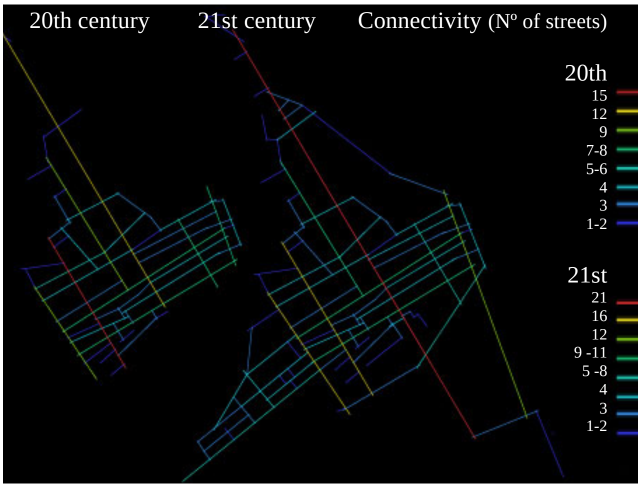


Figure 3: Connectivity's axial maps of the urban centre on the beginning of 20th and 21st centuries, respectively.

2.3.2 Global and local Integration

On the global integration map it is analyzed the potential of topological accessibility calculated for the entire system and considering the global properties, Rn, where the variable "R", correspond to the radius, which means how many axes we account from any place of the system, and "n" the unlimited number of possible connections. We also calculated the local integration map, at a third level, R3 (radius 3) which coincides with the potential properties at a local scale, where it is considered only to three lines that follow in any direction from a certain line (Hillier, 1984).

When we compare the global integration to the urban core, in range of a century, we verify that the level of integration remains the same (100 percent) but when we compare the urban core with the new urban area, this parameter reduces drastically (56 percent) which is justified by the rural character outside the perimeter of historic core.

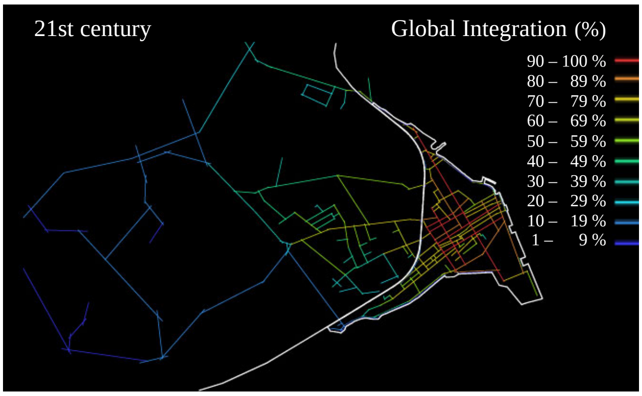


Figure 4: Global integration’s axial map of the town’s area.

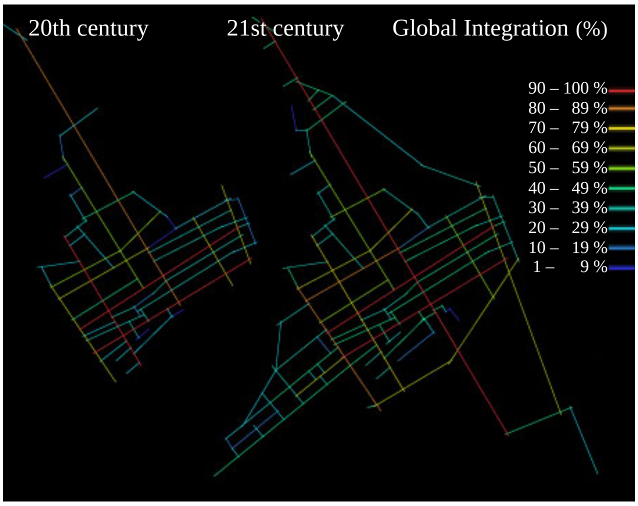


Figure 5: Global integration’s axial map of the urban centre, on the beginning of 20th and 21st centuries.

On local integration, assuming R3 (radius 3), there was a slight increase of 105 percent, due to the opening of a residential block at south part of the urban plan, increasing the north-south main axe. More significantly is the comparison between urban core and urban area, were it is observed reduction of 75 percent of the local integration.

We come to the conclusion that the territorial expansion of the last hundred years has not contributed to increase integration, which should be a point to improve on future planning.

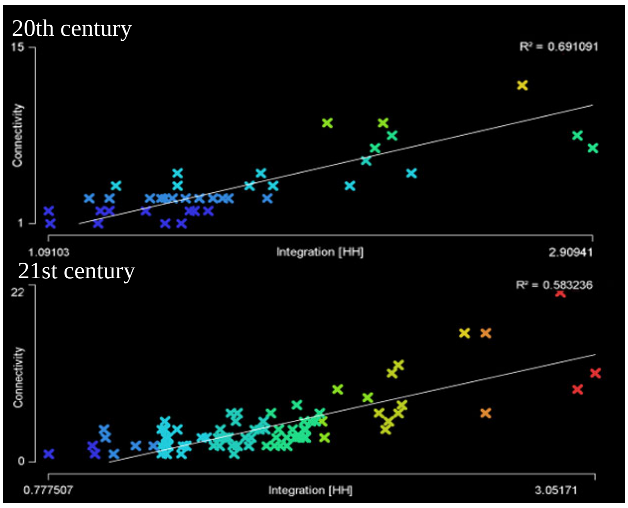
2.3.3 Intelligibility

The Intelligibility concept applied to space analysis corresponds to the correlation between connectivity and global integration’s values of the axes in a specific system, resulting in the coefficient of determination, which indicates the degree of dependence of one variable to another.

This coefficient is closely related to the existence of long axes that cross the whole system. If the system has just a few global axes, there is less changes to be intelligible, and the global - local relationship is compromised because of the difficulty to realize the entire system (Medeiros, 2006).

The perception is made by parts and consequently restricted to certain areas of space. This principle is associated with the notions of topological perception (Kohlsdorf, 1996) concerning to the difficulties or facilities in the orientation and location of the people passing through urban space. So, the addition of new segments or changes in the geometry of the city tends to cause fragmentation in the configuration, by breaking the continuity of space (Medeiros, 2006). That’s why on the study case the intelligibility factor is the most decreased.

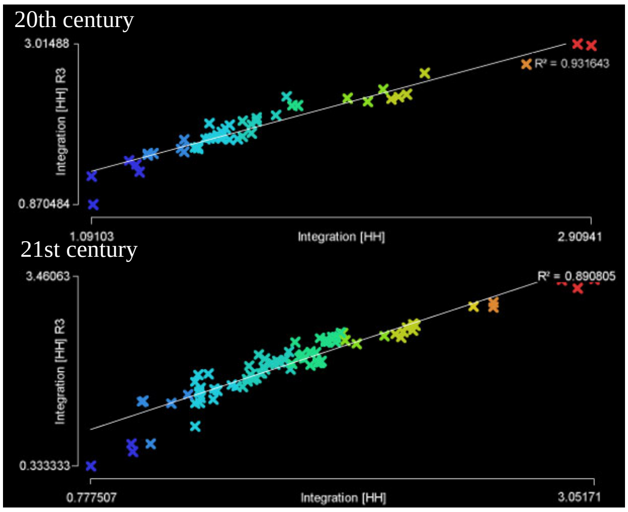
Comparing the urban core with the village’s area, intelligibility dropped 36 percent. This is due to the expansion of an orthogonal urban core to an organic fabric with rural characteristics.



Graphic 6: Intelligibility’s graphs of urban centre, on the beginning of 20th and 21st centuries, respectively. Represented points correspond to segments on the axial map.

2.3.4 Synergy

Concerning to the study of space syntax, synergy consists in the synchronization degree of the balance between global and local integration’s levels, measuring the dependence of a variable to another. This parameter is analysed by the coefficient of determination for the correlation between the values of global integration (Rn) to local integration (R3) for all axes of the system (Medeiros, 2006). On this study, the parameter comes more significantly when comparing the urban core with the urban area, reducing 78 percent, in view of the comparison of urban core during the 20th and 21st century, with a reduction of just 95 percent.



Graphic 7: Synergy's graphs of urban centre, on the beginning of 20th and 21st centuries, respectively. Represented points correspond to segments on the axial map.

2.4 The Visibility maps

The visibility maps analysis (known also as VGA maps) gives the opportunity to make a local interpretation of the model, which in the study of specific points of the network is appropriate. The local model measures are based on the relationships between each node and the nodes directly connected to it. Through the visibility graph (VGA step-depth metric measures map) are calculated for each node, the shortest path to any point within the graph, considering the fewest number of turns.

2.4.1 Visibility maps procedures

The VGA map is created by importing the 2D-CAD village's urban plan into the Depthmap Software and then submitting to a grid of points that will be part of the graph over which the analysis' parameters will run. The grid spacing can be chose between 1 and 5, even though default spacing can be set automatically according to the dimensions of the drawing and its complexity (to this study it was applied a grid spacing of 5, due to the orthogonal plan). After apply the grid, the visibility graph is created. The connections representing the visibility of points are colored according to how many other locations are visible from it. The range runs from blue (for low) through green and yellow to red (many visible locations).

Once the graph is created, simple measures can be analyzed, as the step depth, or the distance (visibility, metric or angular) from one point to all other locations. Step depth illustrates the number of steps (changes of direction) it would take to get from the selected location to any other location in the graph. In this study it was choose the town's main squares.

2.4.2 Step Depth visibility's maps of main squares

On this point of the study, the aim is to compare the step depth VGA's parameters of the urban core's main squares of 20th and 21st centuries, and analyze the spatial relationship between them and their changes on time. According to some testimonials, the two communities of Fuseta (Seamen and Landsmen) were separated by their economic activities, lived in isolated neighborhoods and had different squares as central points (Ramos de Oliveira, 1971). Before the urban expansion, during the 20th century, the Seamen Square dominate the southwest area of the village, corresponding to the high point, the hill, and the access to lagoon's territory, whereas the Landsmen Square controls the central area on northeast and main entrance in town.

However, we can recognize that the main point since last century is the Dock Square, where ends the main streets of each neighborhoods, making a link between both spaces. This quality is more perceptible on the 21st century graph, with the expansion axes along the riverside to the new beach's area.

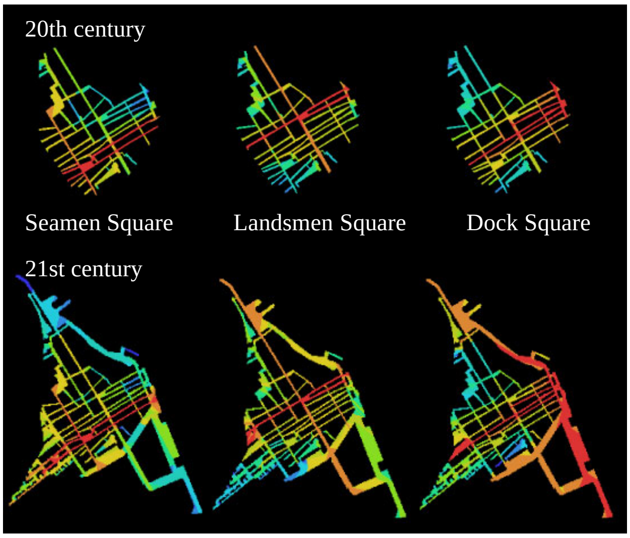


Figure 8: Metric step depth visibility's maps of main squares, on the beginning of 20th and 21st centuries.

3. CONCLUSIONS

The analysis of axial maps of Fuseta's urban core and urban area in the last hundred years, allowed us to understand that the original orthogonal structure of the urban fabric core lost their characteristics with the growth to new rural areas, following an organic design induced by natural limits.

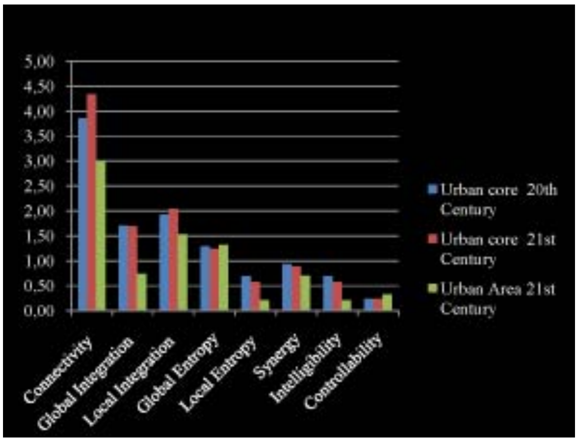
Most of the parameters studied had an increase when comparing inside the urban core, which means that the structure has the capacity to absorb the new changes without losing its design characteristics. In respect of the evolution of urban area in its totality, most of parameters deeply declined, revealing that recent organic design is not so sewn to the old orthogonal fabric, having negative holes and interruptions.

With regards to the visibility maps, they answered some previous questions made about the characteristics of the squares, their relationship and its function on global system. The underlining of other potential areas with high capacity of connections that they are not being exploited yet, are also a positive aspect.

The production of axial and visibility maps substituted for the lack of documents, making it possible, from now and in the future, to characterize urban morphology during past periods, without information sources.

Parameters (average)	Urban core 20th Century	Urban core 21st Century	Urban Area 21st Century
Connectivity	3,85	↑ 4,34	↓ 2,99
Global Integration	1,71	↑ 1,7	↓ 0,74
Local Integration	1,93	↑ 2,04	↓ 1,53
Global Entropy	1,29	↓ 1,24	↑ 1,32
Local Entropy	0,69	↑ 0,58	↓ 0,21
Synergy	0,93	↑ 0,89	↓ 0,7
Intelligibility	0,69	↑ 0,58	↓ 0,21
Controllability	0,24	↑ 0,24	↑ 0,33

Table 9: Comparison of parameters analysed by UCL Depthmap Software, concerning to the urban core on the beginning of 20th and 21st centuries and today's urban area.



Graphic 10: Comparison of parameters analysed by UCL Depthmap Software concerning to the urban core on the beginning of 20th and 21st centuries and today's urban area.

Depthmap software is an important tool for predicting the future of urban evolution, to identify the potential and problematic areas and to simulate projects and urban interventions, test the ideas of urbanism and analyze the behavior of the urban organism when subject to changes, revealing being a useful tool for multiple professional research teams.

In conclusion, this study demonstrates the advantages of joint working procedures of new technologies in parallel with traditional methods of research, helping to understand, preserve and intervene in cultural heritage.

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GIS AND 3D MODELS AS SUPPORT TO DOCUMENTATION AND PLANNING OF THE BAKU HISTORICAL CENTRE (REPUBLIC OF AZERBAIJAN)

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KEY WORDS: GIS, 3D MODEL, CONSERVATION, HISTORIC CITY, SPATIAL ANALYSIS, GEOREFERENCING

ABSTRACT:

The walled city of Baku, Icherisheher has been described as one of the best examples of a city that has retained its historical stratigraphy in over a thousand years, where the different influences and its evolution in time may be appreciated. In realising the Master Plan of the historical city, many problems were solved with different information technologies (GIS, DEM, DTM, etc.) for the survey and data mapping management during all the phases of the project. Initially the analysis was addressed to systematic reading of the documents collected during the iconographic study, verifying the process of deterioration that the historic city had suffered during various periods from the Khans to the Tsarist domain, and from the Republic of Azerbaijan to the Soviet period through to its independence. The entire central part of the historic city was analyzed, including not only on its special architectural and urban monuments, but even minor buildings, which are in part still intact, used as a basis for a digital map created in order to focus on Baku’s historical evolution. A three-dimensional model of the historic centre of Baku was then produced as a basis not only for virtual navigation in real time, but as additional support for planning studies and to better understand the principles of various design choices. The request to produce a model in VRML format addressed the choice of better modelling methods. The combination of these different technologies and their application in the analysis of historical cities led to further considerations on data acquisition systems, standardization of formats, the use of survey instruments and the use of different software, etc., all fundamental elements to the define their correct use.

1. INTRODUCTION

The ancient city was stratified in time with morphological and structural parameters that originated from cultures that progressed in a correlated manner with the development of urban economy, that was initially mercantile, later commercial and finally industrial. With the advent of capitalism and the birth of the extractive and industrial economy, these relationships changed and the pace, which was asynchronous with respect to the adaptation potential of the urban structure, had an enormous impact on the historical stratification of the city, producing functional modifications that changed the city from a unitary whole to a structure used only in parts. Recovery of the ancient city, intended not as a fait accompli incompatible with its current functional needs, but an important element of the democratic use of its cultural, social and economic heritage, must necessarily be based on research work and analysis of these stratification, expansion and alteration processes, considered however from a new perspective, namely no longer interpreted empirically simply from an historical point of view and isolated from the factors that induced the same, but seen in a broader social, political and economic sense and above all in their original symbolisation, without filtering the same through the Russian literature of the nineteenth century and beyond, which is something that today is still intentionally done. While recognising today that the historical centre of di Baku is the ultimate result of a unitary process of historically complete formation, it is however possible to clearly re-interpret the single “stratifications” of this process of formation. When Baku, which was founded as a mercantile trading post at a port along the silk road, became a commercial city it underwent a first planned transformation when it was chosen (XVth century) as the capital of the kingdom of Shirvanshah and was characterised by a strong interpenetration of different social classes. Over the years the city played a double role: as commercial centre in the upper part of the city around the fortress of Shirvanshah, and as trading post in the lower part of the city, next to the Silk Road between the Southern and Northern parts of the city, facing the port where the third city gate was located. The two sections of the city coexisted but there was no interpenetration, so that while the upper town was above all used for residential purposes, the lower town city was characterised by bazaars, caravan ins, the central mosque, workshops and storerooms. The city walls were completed in the XVth century but outside the walls there were villages which were contemporaneous if not prior to the city itself that for years housed the fortified residences of different governors. Thanks to its commercial and market activities, the city became a flourishing cosmopolitan city and a point of reference for the entire Transcaucasian area, even along the sea routes of the Persian and Russian empires. It was for this very reason that it was disputed by these two great powers, until towards the middle of the XVIIIth century and the early XIXth century, it was finally occupied by the Russian empire. Between the XVth and the XVIIIth centuries the most important changes were to the defence lines, to which a second fortified boundary wall and bastions were gradually added. With the advent of the Russians, the city which up to then had adapted synchronously to different cultures and had a uniform urban fabric with its own architectural features, underwent a traumatic transformation. From a gradual process of stratification of styles and features, the city underwent a drastic “superimposition” of typically Russian buildings. From a cosmopolitan socially interpenetrated centre, the city became a centre of occupation. After building infrastructures of authority and power such as army barracks, administration headquarters, prisons and so on, the Russians gradually proceeded to demolish the signs of the past. Many mosques were deconsecrated and the homes of the more prominent families destroyed. The identity of the city itself was denied. After building a new city on the exterior, presumably where the fortress of the last Khan stood, the Russians proceeded to disintegrate the historical urban fabric by demolishing many defence features (walls and bastions). Even the dock facing the historical city was replaced by a linear port that extended along the coast. On this new clearing a curtain of new commercial buildings was raised to hide the city itself. In 2002 the city was listed as a UNESCO World Heritage site to support conservation and protection processes, above all because degradation and destruction of monuments and buildings of the traditional and historical fabric had significantly compromised its architectural integrity, in particular after the earthquake in 2000. Only from 2000 to 2009, after the UNESCO listing, was it considered to be important to create a general plan containing guidelines that would uniform the urban fabric in the territory, by incorporating past provisions and introducing new rules in order to create an efficient reference law.

The creation of an efficient Master Plan also meant the introduction of a very important monitoring phase. This made it possible to document the changes that had occurred and effectively compare current conditions and future objectives. The monitoring phase includes regular controls but only once responsibilities and method of collaboration between the various authorities have been defined.

2. THE BAKU GIS: A NUMBER OF PROBLEMS

Research work and analyses focused on the phenomena of genesis which are still present today, attempting above all to localise the processes which with the advent of Russian domination altered these phenomena, and produced the current physiognomy and use of the Historical Centre. A methodological interpretation of the genesis, based on reliable visual records, firstly summarises a systematic analysis of the formation of the city, focusing on the generating elements, and then verifies the process of alteration that the city within the walls underwent in two hundred years of Tzarist domain and seventy years as a Soviet Republic. This analysis of the Historical Centre, intended not only as monuments of particular architectural and urban importance but also the lesser urban fabric, which is substantially still intact, is the basis of the digital map produced to represent its historic evolution.

2.1 Georeferencing

The particularity of a GIS project is that in order to represent and manage the spatial information of a specific territory, it uses a representation of spatial data separated from the physical reality but defined by a specific spatial reference system on which the data are entered. The geographic dislocation of each part of the computer system is indicated by a specific Reference Geodetic System which makes it possible to georeference the project.

When working in field like that of cultural heritage and dealing with international projects and problems, it is essential to use a georeferencing system which is recognised and applied at a global level to plan the project. The only geodetic system which meets this requirement and is applicable on a global scale is the WGS84 (World Geodetic System 1984, world geodetic system referring to 1984). Traditional geodetic systems are in fact generally based on ellipsoids positioned in space, using the astrogeodetic method, tangent to the local geode in a central point of the area in question; the ellipsoid associated to the WGS84 not only has a different shape and dimensions but its geometric centre coincides with the barycentre of the Earth and with no relation to its surface. It is a mathematical model of the Earth from a geometric, geodetic and gravitational point of view, but because it is based on a system of geographic coordinates, it has two fundamental disadvantages: the use of decimal degrees as unit of measure that do not permit aerial processing of the various items and polygon distortions which depend on the land surface of the area in question, and which increase proportionally the further you move away from the equator. These problems are resolved however thanks to the fact that the WGS84 associates perfectly to UTM plan projection (Universal Transverse Mercator). This system subdivides the terrestrial surface into 60 time zones having 6° longitude as from Greenwich, and in 20 bands having latitude of 8°. Intersection of the time zones and bands generates 1200 zones which in turn are subdivided into squares with 100 km sides, marked by two capital letters. The project can therefore be georeferenced by identifying the area in which the cultural heritage is located, using a metric system and preventing distortions. The system is also fully compatible with the WGS84, so that the shapefiles created in the various UTM systems may be all be imported into a single project in the WGS without transformations. Considering the above, the WGS 1984 UTM Zone 39N was chosen as the reference system for the GIS project for walled city of Baku. The first step was to import a "cleaned" map produced with CAD software into GIS environment, in order to have a database with which to start constructing the space in question. The entire historical centre was thus created, polygon by polygon, identified by the shapefile "Buildings", to which further layers such as "External-buildings", "Walls", "Green_areas", "Green_areas_centre", "Caspian_Sea" were added, and assigned to the respective shapefiles in order to complete the map square representative of the territory. Once the map construction of the area had been completed, a data platform was created for *queries* , by entering in the table the characteristics of the building number, the block number, the Mahalla number (local subdivision of the block), address and street number, ownership (whether public or private), use, type of building, periodization, state of conservation and planned restructuring works, in order to provide to planners a large number of data to identify the single building units and manage the urban functions of the territory. The building categories grouped by historical period, to which their genesis refers, were also taken into account. The aerial dimensions of all the buildings in each group were then calculated and associated to the entire extension of the building fabric of the historical centre.

2.2 Spatial Analysis

The Spatial Analysist tools of the ArcGIS make it possible to explore and analyse data according to their spatial position and weighted data in order to obtain a fuzzy logic (FL) based aerial view. In this context, the FL provides a simple way to reach conclusions on the basis of data which are at times not only vague and ambiguous but even inaccurate or altogether missing. Fuzzy Logic queries and changes the concept of binary logic according to which data may only be either true or false. When applied to the territory and environment, binary logic is imprecise and does not correspond to reality which includes many-faceted aspects that are not taken into account or rather approximated with this method of interpreting space.

In the real world and in this specific case, a number of particular characteristics were taken into account, such as the State of conservation, conservation works, aerial dimensions and historical period defined by points. Each of these aspects is defined in the characteristics table by various classification categories on the basis of which values in a scale from 0 to 1 were allocated, with growing importance to l'1. Consequently the oldest areas, those characterised by better conservation and key buildings having an important function in the city are graded as 1, scaling down to zero as importance decreases. These parameters may reciprocally impact each other according to proximity of the points and interactions between the various characteristics that may be evaluated using the extension Spatial Analyst di Arcgis of ESRI. This tool makes it possible to process interpolations thanks to which the intermediate values of a function may be estimated according to geographic proximity logics. Arcgis has various moving-average interpolators: IDW, Spline, Kriging and Natural Neighbour. These systems are used to calculate the values of areas when data are not available for the variable described with algorithms that calculate the average of points in proximity of each cell, inversely weighted with respect to the distance, also taking into account in some cases the autocorrelation of the points measured. In other words, the values of the grid cells do not only depend on the value of the known points but also on their spatial layout. In this way each point is not simply evaluated as a unit in itself but the interaction of the environment on the same may also be evaluated. Significant interpolation is obtained from the real representation of the influence that urban mosaics share. This was the reason to identify this complexity, which according to the data entered, reprocesses a new and different concept that does not simply reflect what has already been observed.

The comparison algorithm is based on the concept of Natural Neighbours and Voronoi polygons. The Voronoi diagram is a special decomposition of metric space determined by the distance to a specified family of objects (subsets) in the space (for example a finite set of points as in the case of the points described in this project).

In the simplest and most common case of the plane, given a finite set of points S, the Voronoi diagram for S is the partitioning of the plane that associates a region V(p) to each point P belonging to S in such a way that all the points of V(p) are closer to p than to any other point in S.

The natural neighbours spatial interpolation method was developed by Robin Sibson [1] based on the Voronoi diagram of a discrete set of points distributed on the Euclidean space. This algorithm does not arbitrarily define the surface and also offers the following advantages: it respects experimental data without filtering the same and the resulting surface is regular (continuous and to the first derivative, derivable anywhere other than on the data observed), thus approximating the phenomenon interpreting as “faithfully” as possible.

The equation in a bi-dimensional space is the following:

$$G(x,y) = \sum_{i=1}^{n} w_i f(x_i, y_i)$$

Where

$G(x,y)$ is the estimate to the position (x,y)

w_i are the weights

$f(x_i,y_i)$ are the known data for the pair of coordinates (x_i,y_i)

This method proposes a measure to calculate the weights and select the neighbours to interpolate. It also uses the Voronoi diagram to calculate the weight associated to each point.

Given the Voronoi diagram for a distribution of the points in space and given a regular interpolation grid consisting of a finite number of points that we will call p_i, the method considers the Voronoi diagram to calculate the weight w_i of the node of grid p_i as shown by the drawing

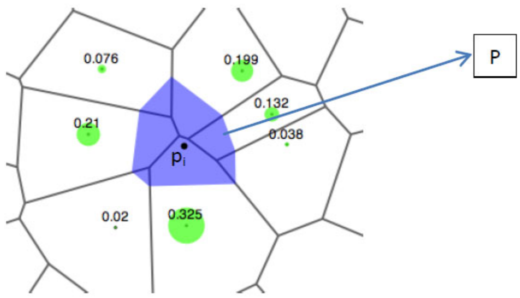

Figure : Interpolation of natural neighbours, calculation of the weight

The weight is calculated according to the area given by intersection of P with the existing polygons, so that a larger area corresponds to a higher weight. Thanks to the weighted subdivision of the space studied in adjacent areas, the Voronoi diagram makes it possible to study the spatial distribution and continuity of the phenomenon. Areas with a higher number of points and where the phenomenon is more uniform, may therefore be identified by appropriate teeming.

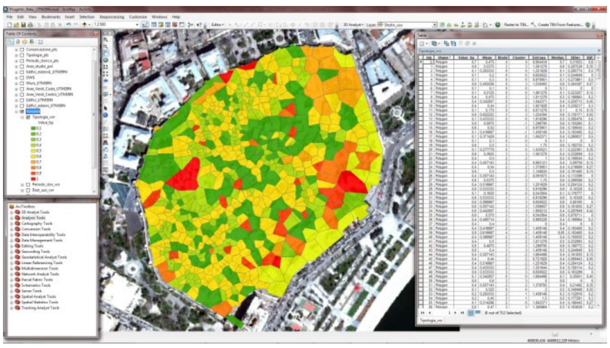

Figure 2: Processing of the area by Voronoi Diagram

Interpolation on the other hand “flattens” the data on a regular grid, representing the phenomenon in the form closest to real life. Natural neighbour interpolation may be used to highlight continuous structures in the space.

In this project, the Voronoi diagram was generated with the “Create Thiessen Polygons (Analysis)” function while natural neighbour interpolation was calculated with the function “Natural Neighbours” in the “Spatial Analyst” Toolbox.

The rasters obtained were displayed according to a signal scale with 3600 colour shades ranging from green (low values) to red (high values) through yellow (medium values), based on fuzzy logic. The different rasters were then overlaid using the Overlay tool in Spatial Analyst Tools, called “Fuzzy Overlay”. The function “AND” was then used to join the rasters defined by “stretched” symbology to create a new single raster.

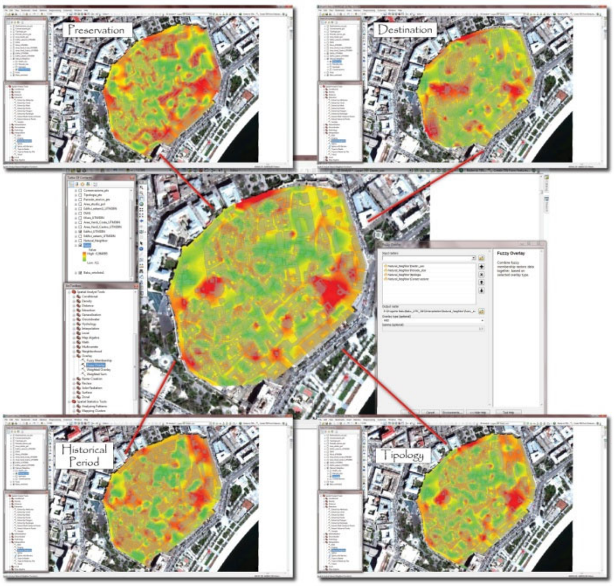

Figure 3: Different rasters obtained by "Natural Neighbour" interpolation which were then summed according to overlay logics between fuzzy rasters

This above shows that the most interesting section in terms of conservation is that in the North, East and South where connectivity is high so that minor interventions would easily improve the architectural value as a whole, while more significant interventions would be necessary in the central and western areas which are smaller and more detached from each other. This type of visualisation complies perfectly with FL since the territory is not visualised by discrete entities but as a continuous territorial fabric, gradually passing from a lower to a higher value. This undoubtedly innovative and on the whole analytic methodology quite obviously does have some limits, the most significant of which involves the edges of the interpolation area. In proximity of the outlines, there is an objective limit in terms of calculating the reciprocal influence between different points, in that the points on the outer edge of the area cannot interact with the territory beyond this and even if contiguous with the same, cannot in any way affect the final result. Interpolation in fact "invents" points on the edge. To remove these, a clip polygon must be created, which limits processing to the perimeter of the points provided: the operation was carried out by extracting the perimeter of the data available (grid complete with valid grid nodes) and clipping with ArcToolBox/Spatial Analyst/Extraction/Extract by Mask.

3. MODEL OF THE HISTORICAL CITY

A 3D model of the historical centre of Baku was then produced, not only to allow virtual navigation in real time but as additional support to planning in order to better understand the various project choices. The need to produce a model in VRML format addressed the choice of methodologies to use in modelling. Work was based on the urban structure of the city and a separation of individual areas into single objects with various levels of details; in addition to modelling activities, images to apply to the faces of the model were produced, through to completion. This format, which is a simple open text file (which is not coded and can therefore be modified with any text editor), permits entering the characteristics of the model polygons. Vertexes, edges, surface colours, textures, brightness and transparency etc. may be defined in the same. Regardless of the software tool used for modelling, the same would need to produce objects consisting of basic units, easily convertible to this format (WRL). Low-poly modelling was also clearly necessary, in other words using the lowest possible number of polygons, in view of the numerous objects to represent at the same time. Generally speaking, all the CAD programmes which operate in a 3D space, have these characteristics. The apparently obvious of using AUTOCAD (Autodesk) was made for three main reasons:
- the fact that it is commonly used;
- the fact that the file structure may be rigidly organised, by controlling the levels (layers), colours (no more than 256) and names of the latter (and thus using specifications common to all the models);
- the fact that the software can generate an interexchange format comprehensible to the software used to allocate the textures (maps) to the surfaces of the models. Version 10.1 of Cinema 4D (Maxon) was used for this. This packet was preferred over more popular packets such as the 3DS MAX (Autodesk-Kinetix), because of its tried and tested strong points: operational stability, extreme flexibility for the management of complex objects, good compatibility in terms of importing and exporting other formats.

Organisation of the basic material suggested right from the start the possible organisation for the management of 3D data. A "minimum" element identified in the fairly chaotic urban context, which developed within a wall hemicycle in fact included the so-called "Isolated" elements. Each of these is a unique element, enclosed in itself, that may therefore be treated as a separate element in the model as a whole. Joining all the isolated elements (approximately 99) within the city walls, would have represented the building volumes as a whole of the ancient part of the city. A structure of this kind made it possible to take into account, within each "Isolated" unit, the sub-units of which the isolated unit consists, namely the Elevations (total fronts on one side of the isolated element) and the facades of the single buildings, of which the Elevations are in turn composed. The documents showed that on average each isolated element consisted of 4-5 Elevations which in turn consisted of a variable number of individual buildings, corresponding to several hundred single buildings. Some isolated elements consisted of just one building, while others consisted of dozens of different buildings. Entering the isolated elements into a single C4D file, produced an object in which the reciprocal planimetric position of each isolated element was that of the original plan. There were some instances of interference and overlapping (but only of sections of isolated elements), that were resolved by selecting and moving the vertexes in question, with respective "deformation" of the original geometry. These modifications were on the whole not extremely visible, thanks to re-adaptation of mapping to the surfaces. There movements in any case occurred in small circumscribed areas and were resolved locally, without repercussions on the general structure of the isolated elements themselves. Overlapping was mainly due to the smallness of the spaces that separated the isolated elements. In very many cases, the total width of the alley was less than a metre. The "global" file had a hierarchy of a total of 96 isolated elements, ordered in sequence (isolated elements 1, 74, 75 are missing because they were demolished), plus one object representing the walls. Right from the start, the configuration of the ground inside the walls, was founded to be extremely complex. Continuous ups and downs, above all on the fronts, indicated a very uneven morphology, with many points of discontinuity, differences in level, steps, uphill and downhill slopes, which in many cases were very steep. This led to the idea of using the "profiles" in the facades to generate surfaces locally that, when summed, would give an acceptable basic closure. Because of the way the project was structured, it would not have been possible to model the ground until all the isolated elements and relevant mapping were completed. An alternative might have been to carry out modelling and mapping, by contrasting isolated elements, but this would in any case be difficult because of the way the work loads had been shared between the modellers, and the different times required to complete the different parts. Although the methods created to produce and control the built-up parts of the city were complex, they gave excellent results. The model of the isolated elements is, in fact, as far as possible and given the data available, scientifically correct and easy to use. Other than in a very few cases, which were in any case resolved fairly easily, there were no particular cases entailing survey or modelling errors, that precluded the closure or resolution of the single isolated-units. The altimetric aspects and resolution of the basic ground were a different matter. These aspects in fact caused the most critical problems. In the case of Baku, it will be shown that the new three-dimensional processing carried out in different 3D environments, may be an efficient representation of the urban fabric, which may generate new knowledge and studies in the field of urban sciences.

The new potential of digital representation of urban spaces is radically changing the way the city is studied and analysed. Many studies have attempted to explore the possibilities of 3D representation of the city, even in terms of defining new forms of analysis and interpretation, through the perceptive interaction this modelling permits. 3D models make it possible to represent the physical structure of the city, which may in turn be analysed, in order to define how a residential or cultural urban function characterises a specific context and relationships with other activities, thus representing an efficient possibility of investigation and documentation developed thanks to the new three-dimensional representations of urban space. It is important to note that over and above its theatrical effects, three-dimensional modelling is extremely useful to analyse aspects that may also easily be represented in 2D, but which provide better data through graphs, showing the actual conditions. The main characteristic of these models is that they contain a wealth of different kinds of data from different origins. The data sheets that complete the detailed conservation Master Plan, aim at defining a new field of analysis and interpretation of the historical city and would seem to be a valid support to decisions in the different government areas of urban transformations, in terms of recovering and protecting the ancient fabric of Baku.

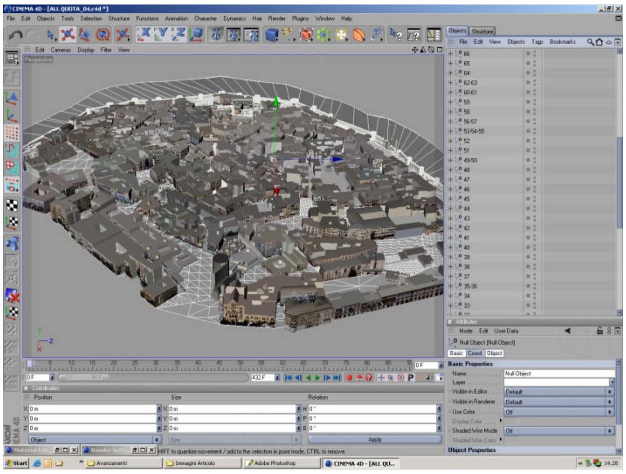

Figure 3: The “global” file presented a hierarchy of 96 blocks altogether, ordered sequentially plus an object making up the town walls.

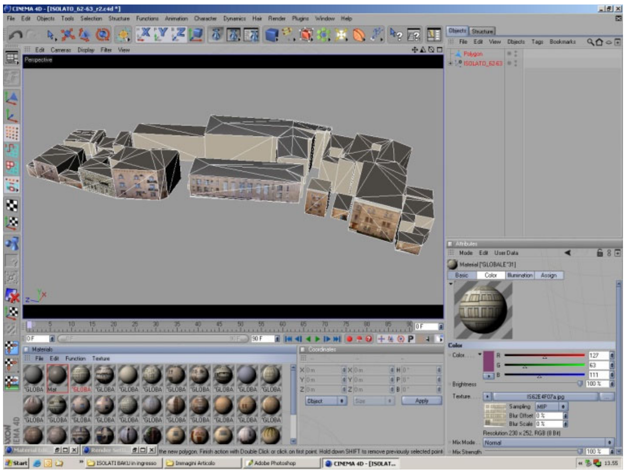

Figure 4: Inside, each block presented the hierarchy described and finishing the model and each could be managed independently from the other.

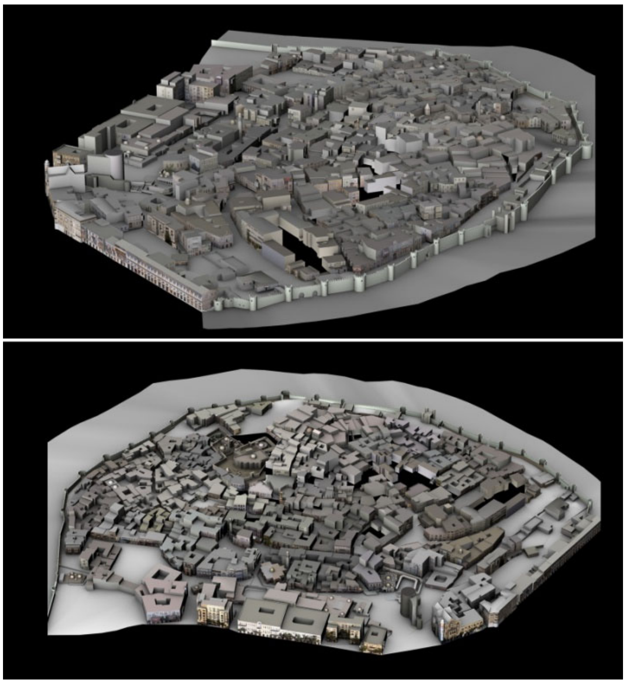

Figure 5: 3D Model of the Historical City

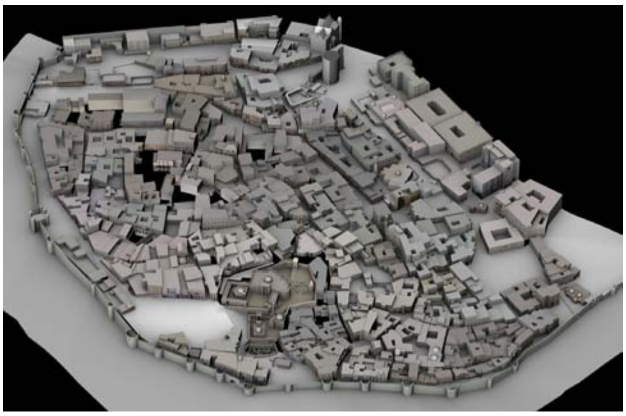

Figure 6: Detail of 3D Model of the Historical City

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GEOGRAPHICAL INFORMATION SYSTEM FOR THE CULTURAL HERITAGE AND PROTECTED LANDSCAPE OF REGIONE TOSCANA

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KEY WORDS: Cultural Heritage, Conservation Measures, Geographical Information System, Cartography, Regione Toscana, Ministero per i Beni e le Attività Culturali

ABSTRACT:

LaMMA Consortium, with collaboration of Regione Toscana and Ministero per i Beni e le Attività Culturali (MiBAC), has created the web Geographical Information System for Cultural Heritage and Protected Landscape of Regione Toscana. This system now makes it possible to access the digital maps and the digital archives of archaeological, architectural and landscape related restrictions over the entire region. In order to continuously update the realized system for maintaining its utility and validity, Regione Toscana together with MiBAC signed a protocol agreement (2004), according to which every new restriction measure issued is sent as a copy also to the regional offices and then to LaMMA Consortium, that attends to update the digital archives and the digital maps. Thanks to this agreement, the system counts today over 18,000 measures, with an average yearly increase of almost 250 measures, that determine restrictions for 9.000 areas.

1. INTRODUCTION

In the period 1999-2001 Regione Toscana, in cooperation with the Laboratory for Meteorology and Environmental Modelling (now LaMMA Consortium), took part, together with other Italian regions and the Istituto Centrale per il Restauro (ICR) branch of the Ministero per i Beni e le Attività Culturali (MiBAC), in the European Project INTERREG IIC Medoc named *Risk Map* (Costantini, 2001a; Costantini, 2001b).

The experience gained, thanks to the project, drew attention to the fact that the archives of the several Soprintendenze[*] are not easily and quickly accessible and it is not always possible to exactly locate the assets because of the enormous quantity of documentation produced in more than one century of activity (the oldest protection act refers to law number 364 in 1909), and because of the cadastral and toponymy changes that took place in this period (Costantini, 2001c).

In this context a follow-up regional project *Carta dei Vincoli* was realized (2001-2003), evolved into the Geographical Information System for Cultural Heritage and Protected Landscape of Regione Toscana. This system gives today the possibility to access the digital maps and the digital archives of archaeological, architectural and landscape related restrictions over the entire region.

In agreement with MiBAC, in order to obtain a homogenous product able to give unambiguous information[**], the survey was focused on Cultural Heritage with explicit conservation measures, postponing the examination of all other assets filed or registered, in the second instance. This made it possible to create a tool directly usable by the local administrators, to access and locate all measures with legal effectiveness that are subject to specific governmental discipline.

[*] Peripheral organs of the Ministero per i Beni e le Attività Culturali (Ministry of Culture) with the institutional task of protecting, conserving and valorising the architectural and landscape heritage in the territory of competence.

[**] Considering the outstanding amount of data (up today more than 17.000 measures acquired, with more than 85.000 scanned pages) and the historical layering of information.

1.1 Short Historical Excursus on the Conservation Cultural Heritage Normative in Italy

In Italy during the Risorgimento, almost all states had issued more or less homogenous laws for the conservation of the antiquities, works of art and archaeological areas.

The State of the Church was the one that could boast the oldest tradition concerning laws, for example it had edicts for police control on conservation and trade of antiquities and works of art with the purpose of preventing masterpieces destruction and dispersion. In the broad group of laws of the Papal State it must be highlighted a particular measure issued by Cardinal Pacca in 1820, under Pio VII Pope. This was the first homogenous measure to protect the cultural and historical heritage and was the inspiration for similar measures in Naples Kingdom, in Tuscany and in the Kingdom of Lombardy–Venetia.

In contrast in Piemonte there were not important normative interventions, with the unique exception of the Giunta di Antichità e Belle Arti founded in 1832 for proposing conservation measures for antiques and works of art.

Almost everywhere in Italy there was a consciousness raising about the artistic and historic heritage but, with the exception of the State of the Church and Kingdom of Naples, the other states limited their laws in order to avoid the works of art escaping from the state.

After Italian unification, the Kingdom of Italy completely disregarded cultural heritage. With the Statuto Albertino, that ratified properties sanctity, state meddling on this topic was not allowed at all. This was the reason of private initiatives origin. The only exception in this picture is represented by law number 2359 in 1865 about the possibility to expropriate monuments ruined by the owner's negligence.

The first set of laws (number 185 in 1902 and number 364 in 1909) concerning the principle of public significance and the preservation obligation of cultural heritage together with the acknowledgement of the public administration action power, goes back to the beginning of the XX century, when for the first time the public nature of works of art was stated and the necessity of safeguard was recognized.

The first important attempt to give an homogenous and systematic structure to the set of laws concerning the Italian cultural heritage was made through the foundation of a unique Consiglio dell'Educazione, della Scienza e delle Arti only in 1939, with the laws number 1089 and number 1497.

These rules were aimed not only to protect but also to enhance the cultural heritage and related activities, especially through the use of grants and subsidized credit. Anyhow these measures, intended to ensure the fruition and appreciation of those assets, remained in the background compared to those, still predominant, direct to ensure the conservation, protection and enforcement of circulation restrictions.

Only with the Constitution of the Italian Republic, the Italian State action directed to protect and promote the culture, becomes a fundamental principle of the Republic: article 9 does not only to take into account the preservation of cultural heritage, but ratifies the cultural function of the State in the preservation of interests relating to cultural properties.

But the term cultural heritage goes into the Italian system only in more recent times, following the ratification of international conventions after World War II: the term makes its first appearance only in The Hague Convention in 1954. Ten years later, Commissione Franceschini gives an important contribution to the definition of cultural heritage, intending by this term "all assets [...] for the collective fruition - regardless of public or private property - as concrete evidence having culture value".

However, an important innovation in recent legislation is marked by the passage from a legislation substantially made by restriction measures (in 1939), to a dynamic role of cultural policy, which aims to ensure the widest availability of the cultural heritage value. For the first time the State is obliged to bears the costs of restoration if the owner of the asset is not in the position to support them (law number 1552 in 1961); the 1970 Presidential Decree number 805 used the term enhancement for the cultural heritage; in 1982 law number 512 funds allocates and cash donations for the promotion of cultural events, together with interventions to improve safety conditions of museums and cultural institutions; private citizens can be directly involved in the management of ancillary services with fee in museums, galleries, libraries (law number 4 in 1993).

Afterward, the legislature introduced a new important measure with the Consolidated Law concerning cultural and environmental heritage (Legislative Decree number 490 in 1999). The Decree lets the local administration have a broader management role and expands the protection area to photographs, to music papers, films and audiovisual works and other assets which, although not listed, constitute evidence of cultural value.

The new Cultural Heritage and Landscape Code (number 42 in 2004) replaces the above mentioned Consolidated Law. With this Code important innovations are introduced from a revision point of view of cultural heritage legislation in order to organically and systematically regulate the cultural, historical and artistic Italian heritage. An important aspect is the distinction between protection and enhancement, assigning the first to the exclusive state legislation and the second to the regions legislation. In addition the enhancement, that is also considered as a social benefit, is distinguished as deriving from public or private initiatives.

Another significant change concerns the Landscape whose protection and enhancement is assigned to the Ministry in concert with the regions. The Code assigns to the regions the landscape planning task (Costantini et alii, 2004).

2. THE ARCHIVE CREATION

In 2001, with the European project ending, Regione Toscana decided, with the collaboration of the Direzione Regionale per i Beni Culturali e Paesaggistici della Toscana (as a department of MiBAC), to fund the "Carta dei Vincoli" project, commissioning LaMMA to realize the first and as exhaustive as possible, Cultural Heritage Census, that consists, as showed in Figure 1, of:

- a database of all assets and all measures for archaeological, architectural and landscape related restrictions;
- a digital cartography of all constraint areas;
- a catalogue of all scanned documented constraints existing in the Soprintendenze archives.

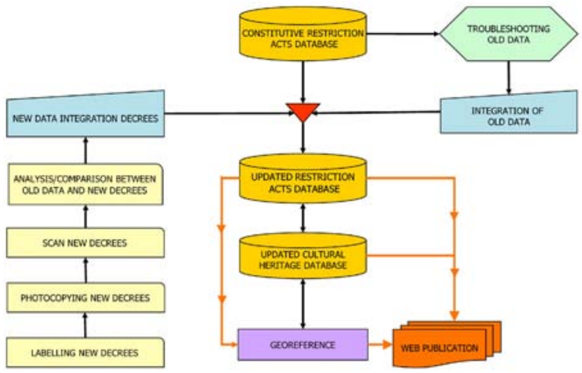

Figure 1: Workflow for realization of the Cultural Heritage Information System.

This first phase, ending in December 2003, let us know the exact amount of the Cultural Heritage in Tuscany: 7,000 archaeological, architectural and landscape areas with more than 15,000 restriction measurements.

Technically the following actions have been taken (Costantini et al, 2005):

1. Documents investigation and selection from the Soprintendenze.
2. Acquisition, through photocopying, of the whole paper documentation, including plans, historical and artistic reports, kept in the offices of the Soprintendenze.
3. Scanning of all acquired documentation, with the realization of an indexed catalogue, that contains about 60,000 images.
4. Creation of an alphanumeric database (*Cultural Heritage* archive), containing all identifying information of the assets subject to the restriction measure (name,

address, cadastral reference, type of restriction measure, etc.).

5. Creation of an alphanumeric database (*Restriction acts* archive), containing indication on all restriction measures for each single area.
6. Realization of digital cartography of areas subject to the restriction measure, congruent with the Regional Technical Map (scale 1:2,000 or 1:10,000).
7. Realization of a Web Portal to access the archives.
8. Creation of an Internet Map Server, integrated with the Web Portal, for Cultural Heritage location on the digital cartography.

3. ARCHIVES ONGOING UPDATING

In order to continuously update the realized system for maintaining its utility and validity (Figure 1), Regione Toscana together with Direzione Regionale per i Beni Culturali e Paesaggistici (MiBAC), signed a protocol agreement (April 2004), according to which every new restriction measure issued is sent as a copy also to the regional offices and then to LaMMA Consortium, that attends to update the digital archives and the digital maps (Costantini et alii, 2007; Costantini, 2009).
Thanks to this agreement, since 2004, LaMMA Consortium update the whole Information System monthly.
As a result of the ongoing updating, up to today (December 2011) the system counts over 18,000 measures, with an average yearly increase of almost 250 measures, that determine restrictions for over 9,000 areas (archaeological, architectural and landscape).

4. THE WEB PORTAL

Through the Web Portal of the Geographical Information System for the Cultural Heritage and Protected Landscape of Regione Toscana (reachable from Regione Toscana homepage www.regione.toscana.it or from LaMMA homepage www.lamma.rete.toscana.it), it is possible to consult both the GIS cartography (Figure 2) and the digital archives of Cultural Heritage with restriction measures (Costantini et al, 2007).
The scanned documentation related to restriction decrees is accessible only to the Ministry personnel subject to specific access credentials (Costantini et al 2007; Costantini, 2009).

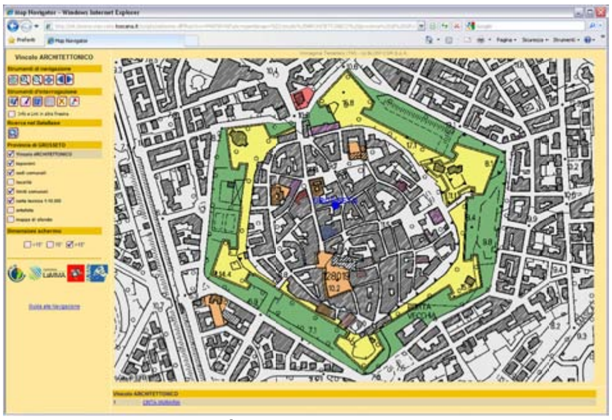

Figure 2: Example of the GIS cartography through the Web Portal

4.1 Restriction Acts Database

According with MiBAC, a specific table has been designed having each record linked to an unambiguous restriction measure (decree, declaration, recognition letter, alienation authorization) (Costantini et alii, 2005).
The fields of the table are:

- *Unambiguous ID code* that identify univocally the single decree
- *Unambiguous ID code* that identify the Cultural Heritage subjected to the restriction measure
- *Name* of the Cultural Heritage like is written on the restriction measure text
- *Province* where the Cultural Heritage is located
- *Municipality* where the Cultural Heritage is located
- *Address* of the Cultural Heritage like is written on the restriction measure text
- *Date* of the issue of the decree
- *Note*: particularity that might exist in the restriction measure text

4.2 Cultural Heritage Database

Since an area can have several restriction measures, the relation between Cultural Heritage table and Restriction acts table is one to many.
The Cultural Heritage table in the database is more complex than the decrees one (Costantini et al, 2005). As a matter of fact the area identification data can derive even from many different restriction measures. It is the case where the Cultural Heritage name has changed in time (i.e. Palazzo Gualfonda ex Giuntini), or where the property is constituted by several cadastral parcels with different owners.
The fields of the Cultural Heritage table are:

- *Unambiguous ID code* that identify univocally the single area
- *Name* of the Cultural Heritage like is written on the restriction measure text
- *Category:* it refers to the architectural type (i.e. abbey, fortification, etc…)
- *Respect Zone:* Direct or Indirect conservation measure enforce to the area
- *Province* where the Cultural Heritage is located
- *Municipality* where the Cultural Heritage is located
- *Address* of the Cultural Heritage on the current toponymy
- *Cadastral References:* group of cadastral parcels of the restricted area
- *Reference Regulations of the first restriction measure issued*: law of the first restriction measure for that specific area
- *Date of the issue of the first restriction measure:* date on the first restriction measure issued
- *Reference Regulations of the latest restriction measure issued:* law of the latest restriction measure for that specific area
- *Date of the issue of the latest restriction measure:* date on the latest restriction measure issued
- *Note:* particularity that might originate from the whole of the restriction measures

4.3 Cartography

In order to represent the real areas subject to the restricted measures, a polygonal cartography for the Cultural Heritage was created (Monti et al., 2004).

The geographic area boundaries maintained in the Cultural Heritage Geographical Database respect the limits of the entities that they represent (e.g., buildings, historical gardens, churches) or on which they are based (e.g., cadastral parcel of land).
Since the input data used to create the Geographical Database was obtained from several sources having a diverse range of scales (Cadastral Map -1:4,000), CTR – 1:2,000, 1:10,000, IGM – 1:25,000), the accuracy* of the polygons boundary is based on the accuracy of the source material used in its production.
In detail:

The areas subject to *archaeological constraint* have been delineated on the base of the cadastral map since the perimeter often does not have a corresponding topographic element on the Regional Technical Map: in extra urban areas without constructions, the cadastral parcels boundary lines were taken as reference.

The areas subject to *architectonic constraint* have been delineated on the base of the Regional Technical Map (in urban areas with 1:2.000 scale, in extra urban areas with 1:10.000 scale), through an interpretation/conversion work of the boundary elements; thereby the resulting cartography is a technical map directly usable for municipality and urban planning.

Finally, the areas subject to *landscape constraint*, although they are originally delimitated with elements of the cartography with a scale 1:25.000, have been delineated on the base of the Regional Technical Map with 1:10.000 scale (Angeli et alii, 2010), through a careful interpretation/conversion work of the boundary elements, that allowed an up-scaling operation.

The resulting cartography is a technical map that is transmitted to the municipalities of the Regione Toscana. They can directly use it in their Geographical Information Systems for landscape planning and environmental management, overlapping the implemented thematic map with other geographical layers concerning environmental risks like landslides, flood areas, etc. (Angeli et alii, 2007).

4.4 Digital Catalogue of Restricted Measures

The Digital Catalogue of restricted measures includes the whole constraint documentation for each Cultural Heritage (decrees, plans, historical and artistic reports, etc.).
Each paper document, obtained through photocopying the original stored by the Soprintendenze, was indexed with an unambiguous numeric code and scanned.

5. RESULTS

All the ten provinces of Tuscany and their municipalities, utilize the products implemented with the GIS for Cultural Heritage and Protected Landscape of Regione Toscana for the execution of their landscape planning activities. This implies a common interest in maintaining the system running and always updated, with the notification of possible inexactness.

6. CONCLUDING REMARKS

The GIS for Cultural Heritage and Protected Landscape of Regione Toscana is constantly utilized by several local governments in charge for land planning (MiBAC, Regione Toscana, municipalities). Additionally also professional categories like architects, engineers and building surveyors, uses the realized system to facilitate the information gathering for their planning activities.
During 2012 the web accesses to the system reached and surpassed the quote of 20.000.

6.1 Future Improvements

In consequence of the aroused interest in the system, a WMS (Web Map Service) is under implementation.
Moreover, in order to provide facilitate access to the GIS for Cultural Heritage and Protected Landscape of Regione Toscana and to share knowledge, would be very stimulating to be part of a cross-domain portal like Europeana. By the end of 2012, after receiving the MiBAC certification, a partnership between the Cultural Heritage Department of Regione Toscana and Europeana is expected.

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* Accuracy: how closely the data represent the real world

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CULTURAL ROUTES AS A SOURCE FOR NEW KIND OF TOURISM DEVELOPMENT: EVIDENCE FROM THE COUNCIL OF EUROPE'S PROGRAMME

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KEY WORDS: Cultural Routes, Sustainable Cultural Tourism, Network Governance, SMEs Generation, Innovation, Trans-National networks, Cultural Tourism Products.

ABSTRACT:

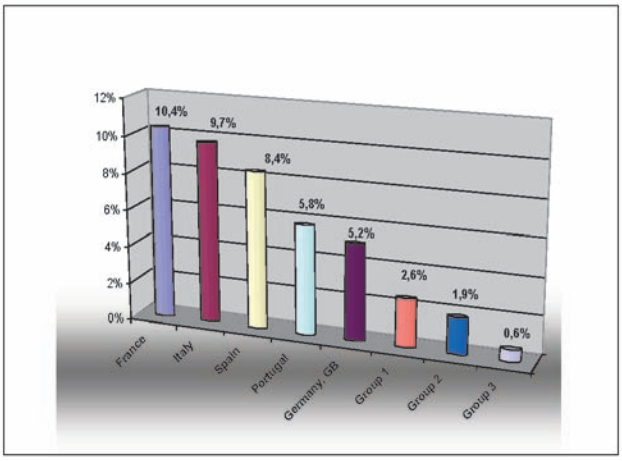
Europe offers a wide variety of cultural itineraries that, crossing several regions or countries, provide a living example of the rich and impressive European common heritage. For more than two decades 24 of such itineraries have been jointly collaborating under the Council of Europe's (CoE) Cultural Routes Programme aimed at preserving the diversity of European culture and heritage, and to promote understanding of Europe's history. Today, when cultural heritage is more and more often viewed as a new form of good - cultural good, - methods of heritage management are changing to incorporate new elements, which could help local communities to draw more obvious benefits from their cultural legacy while preserving and maintaining its uniqueness. Often these elements come from tourism: a new kind of tourism, which is respectful of the environment, of the natural and cultural heritage and of the local traditions. This article offers an overview of the *Study on the CoE Cultural Routes Impact on Tourism SMEs* (Khovanova et al., 2011) that demonstrated how the need for implementing sustainable tourism management practices is growing within the CoE cultural routes. One of the breaking findings of the *Study* was that, even though founded on social and cultural principles, CoE routes today serve as a source of innovation, small business creation, local income generation, and cultural tourism products development. These potentials are now been reinforced by building in sustainable tourism elements in cultural routes management practices, and by bringing the benefits of ICT and digitalization, following the *Study* recommendations. The findings of the *Study* could also help cultural heritage managers and policy makers around the globe to better understand tourism potential of cultural heritage sites, while encouraging respectful and sustainable management approaches.

INTRODUCTION

The Council of Europe's Cultural Routes Programme was established in 1987 aiming to preserve the diversity of European culture and heritage, to promote understanding of Europe's history on the basis of its physical, intangible, and natural heritage, and to improve public awareness about the unique in its diversity European history and culture.

As recognised by the Council of Europe (CoE), cultural route is a cultural project aimed at the development and promotion of an itinerary or network based on a historic route, a cultural concept, figure or phenomenon of a transnational importance that manifests common European values. Extending from the Atlantic to the Southern Caucasus and from the Baltic to the Mediterranean, CoE cultural routes enable improved understanding of the history and memory of Europe in a transcontinental dimension. CoE Cultural Routes Programme comprises 24 certified Routes that cover 70 countries in the world. Statistical analysis of the CoE cultural routes crossings in these countries demonstrated the density of the cultural route networks.

Graph 1 shows the percentage share of the routes' networks by country. France (10.4%) is a leader in CoE cultural routes' networks accumulation followed by Italy (9.7%), Spain (8.4%), Portugal (5.8%), Germany (5.2%) and the Great Britain (5.2%). The rest of the countries contain 2.6% or smaller percentage of cultural route networks density per country. These nations form three large groups that represent the unexploited potential for the CoE cultural routes development in the countries now not well represented, for the future.



Graph 1. CoE cultural routes share per country

Group 1: Belgium, Czech Republic, Greece, Norway, Poland, Sweden, Switzerland
Group 2: Algeria, Austria, Croatia, Cyprus, Lebanon, Morocco, Netherlands, Slovenia, Tunisia
Group 3: Albania, Argentina, Armenia, Azerbaijan, Belarus, Bulgaria, Denmark, Estonia, Jordan, Lithuania, Malta, Romania, Russia, Serbia, Slovakia, Syria, Turkey, Ukraine

While diverse in their cultural legacy, thematic focus, target groups, and network structures, the CoE cultural routes are united in their common goal to manage their cultural heritage professionally and sustainably, in a way to assure its continuous protection and preservation, and to draw obvious benefits from their cultural legacy for local communities along the routes' destinations.

It is this emphasis on sustainable and responsible heritage management - the focal point of which is social wellbeing and economic development of local communities, their environmental and natural resource protection, respect of socio-cultural authenticity and diversity of their cultural legacy and traditions - that makes the CoE Cultural Routes Programme different from similar international initiatives run by UNESCO, UNWTO, the Organization of Ibero-American States, and others.

At the same time, our routes operate equally taking into account and promoting the charters, conventions, recommendations and work of the Council of Europe, UNESCO and ICOMOS relating to heritage restoration, protection and enhancement, landscape and spatial planning. Besides, the CoE Cultural Routes Programme works together with its international partners to develop a coherent roadmap for cooperation between the Council of Europe Cultural Routes and related UNESCO, UNWTO and other programs, especially those already associated with the CoE cultural routes. We aim to establish a competitive and effective joint strategy to preserve the diversity of European culture and heritage, and promote understanding of Europe's history.

THE STUDY

In 2011, the Council of Europe (CoE) launched a *Study on the Impact of the European Cultural Routes* (Khovanova-Rubicondo et al., 2011) jointly funded by the European Commission (DG Enterprise & Industry). The goals of the *Study* were largely predetermined by 'the need of the day' to better understand the reality and nowadays potential of CoE cultural routes following two decades of the Programme operation. These goals were also set in line with the vision of the Europe 2020 strategy, which focuses on policies to create smart, sustainable and inclusive growth, to promote economic, social and territorial cohesion in Europe, taking into account that culture-based activities such as cultural routes projects are capable of making significant contributions to local economies and the prosperity of Europe in general.

More precisely, the *Study* thus aimed to provide insights on the effects produced by the CoE Cultural Routes Programme on local economies in terms of SMEs generation, their performance, network and cluster development; to examine the potential of the Cultural Routes for promoting cultural tourism in Europe; and to analyze how much CoE cultural route networks can benefit local communities, especially in less-known destinations, via SMEs creation. The main expectations from the *Study* were thus to:

- identify key actors involved today in the cultural routes (SMEs, NGOs, associations),
- understand the challenges and advantages of cultural routes' environments (especially in the context of the current economic conditions), and
- estimate cultural routes potentials, their needs and concerns on the way to sustainable cultural tourism development.

Methodology

The CoE team worked closely with the main *Study* stakeholders, group of independent experts, and cultural routes coordinators to design an appropriate analytical framework. At the outset, the study team set up an advisory group with key partners including representatives from the EC (DG Enterprise and Industry, DG Education and Culture), the European Travel Commission, and the European Institute of Cultural Routes (EICR). Considering the complexity and novelty of the field, a consultative group of experts was invited from academia and practice to ensure the input of a range of disciplines, professional backgrounds, and partner organizations, and to guarantee a sound methodology. Key steps of the *Study* included:

- Identification of experts
- Cultural routes Survey
- Creation of cultural routes analytical grid
- Case studies of 5 selected cultural routes
- Intermediary *Study* results
- Transversal themes and issues analysis
- Final conclusions and recommendations

The *Study* included two main phases that followed a CoE-administered survey of 29 CoE-certified cultural routes. This exercise was important not only in terms of current qualitative and quantitative data and information gathering for the selection of case studies but also in a way to assess the overall potential of CoE Cultural Routes Programme development.

The methodology of Phase I was based on a set of case studies of five representatively selected cultural routes - the Hansa, the Legacy of Al-Andalus, the Via Francigena, the Olive Tree, and the Transromanica. A cultural routes' classification grid was created based on the information obtained from the CoE survey and included the following categories:

- Cultural route focus and geographical area
- Type of managing organization (legal entity)
- Number of SMEs and NPOs involved
- New products/posts created
- Sources of financing
- Cultural route network connectivity
- Spatial accumulation
- Existing marketing tools
- Target audience.

The cultural route case studies were selected in close consultation with the *Study* expert group. Each of these studies followed an individual methodological approach most appropriate to its case, designed by the expert working on the study. The goal was to capture in depth as much data as possible from the locations within the cultural route networks. Generally, the methodology of the case studies included the following elements:

- a review of relevant literature and documents concerning the routes,
- desk research: review of the related material and information available online including cultural routes' web pages, open source information,

- meetings and interviews with the key stakeholders of the route that provided a useful overview of the management, key activities, and future plans,
- a survey of cultural route locations-members of the network, and
- data analysis and presentation.

Phase I was completed in March 2011. Its main conclusions and recommendations were presented at the "Innovation and competitiveness within the European Cultural Routes projects: analysis, opinions and perspectives" Workshop in Luxembourg on 28-29 March 2011.

Phase II of the *Study* focused on the transversal issues relevant to all 29 CoE-certified cultural routes and to the environments in which they were operating. In particular, these issues included:

- cultural tourism trends in Europe ;
- cultural routes' management and governance structures ;
- SMEs innovation and competitiveness ;
- branding and marketing of the cultural routes;
- characteristics of the cultural routes' networks;
- the role of ICT in cultural routes marketing and promotion;
- CoE Cultural Routes Programme in the context of relevant initiatives at European and international levels;

Within this phase a number of interviews were conducted by the Council of Europe with international level organizations such as UNESCO and the Organization of Ibero-American States inquiring about the current stage of development and future implementation strategies of the related cultural initiatives coordinated by these organizations in Eastern Europe, North Africa, Asia, and Caribbean. Phase II was completed by the end of May 2011 resulting in seven expert reports.

Main Findings

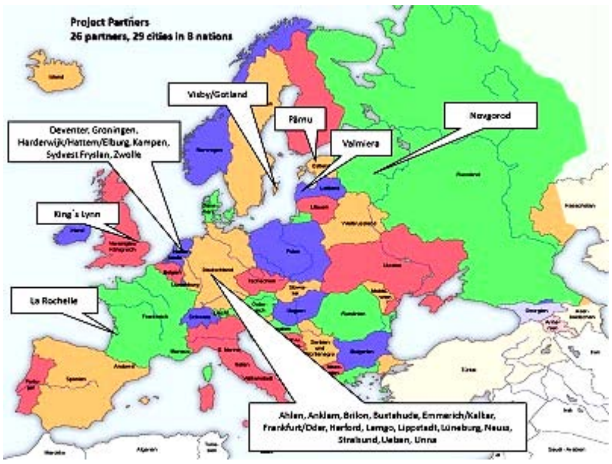
One of the breaking findings of our *Study* was the fact that even though established on cultural and social principles, the CoE cultural routes became a source of innovation, creativity, small business creation, and cultural tourism products and services development within 25 years of their programme existence. We found that, except for ensuring preservation of European cultural heritage properties and promoting common European values, CoE cultural route networks benefit SMEs by providing markets for SMEs products and contribute to tourism revenue generation in remote destinations.

A number of innovative practices were recorded within the SMEs and various routes during this inquiry, with the organizational, product and service forms of innovation being the most noticeable. Within 25 years of existence, our routes have achieved a notable progress, generated multiple positive impacts on the communities along their destinations, and shown enormous potential for SME generation, competitiveness, cross-border collaboration, networking, and promoting European identity in its unity and its diversity. In addition, the CoE routes encourage widespread community participation in cultural activities raising awareness of a common cultural heritage.

For example, case study of the Transromanica cultural route conducted by G. Richards (2011) demonstrates that "there are links with SMEs along the route, mainly in the tourism sector. SMEs are also involved in providing services to the route there, mainly in terms of publications, merchandising and design. Many of the contacts are with SMEs involved directly or indirectly with tourism, such as hotels, restaurants and wine producers. ...According to the project leaders in Vale do Sousa, many of the SMEs in the region are aware of the cultural route, even if they may not participate directly. This includes firms in the major economic sectors in the region, like: furniture making and clothing."

Innovations within the cultural routes: A number of interesting initiatives were discovered within cultural route networks that are instrumental in generating tourism SMEs innovation as well as raising visibility for the routes themselves.

Hansa Business Reloaded project, for example, was developed to set up trade markets between SMEs from different Hanseatic cities. The idea was that the cities involved interested local SMEs to the project to explore possibilities for business cooperation and development trans-nationally. Today, his initiative brings together 26 partners in 29 cities from eight different countries in Europe (see Picture 1 for geographic coverage of the project). This creates the critical mass needed for companies to innovate, to raise awareness about the cultural route, and to provide complete and higher value services and products to their customers. Potentially, this will also generate a higher demand for SME-provided tourism services.



Picture 1. Hansa Route's Business Reloaded Project: geographic coverage

A similar promising initiative in this regard comes from the Transromanica Route that works to establish specific clusters at key locations along cultural routes. This initiative is planned to centre on SMEs, entrepreneurship and tourism. Today, Transromatica offers a selection of tourist packages and trips along the Route in collaboration with local transport companies, hotels, restaurants, wine producers, and tourism offices (Picture 2 below).

Picture 2. Photo of a church from the Transromanica "Romanesque Route of Saxony-Anhalt by bike" tourism offer

The Via Regia cultural route employs the GIS system to inform its visitors and involved SMEs about provided along the route services. This also allows the SMEs to get broader exposure to interested customers and to interact with them directly, while helping to lower the transaction cost for customers and offering a shorter way for SMEs to the market. For the Via Regia coordinators this additionally implies lower administrative expenditures.

The Olive Tree Route has witnessed the organisation of cultural itineraries on request of Chambers of Commerce from several parts of Greece. A number of SMEs along the Olive Tree Route participate in external trade. These itineraries and missions have provided a good basis for strengthening collaboration between the enterprises and to establish a good foundation for new joint initiatives.

All CoE cultural routes provide unique opportunities for SMEs to develop innovative products and services within the framework of tourism activities that the routes generate. These innovation opportunities can be divided into two types. On the one hand, local SMEs produce products and services with a cultural route label, contributing by this to the promotion of a route. These products and services generally involve adoption of innovative solutions, practices and do not require considerable market and/or territorial horizon expansion (innovation adoption type). On the other hand, some SMEs develop their original products and services based on the unique values and heritage of the cultural route they are involved with (innovative product development). These products and services are innovative, since they are new to local SMEs range of activities and practices (Khovanova, 2010). *Table 1* below offers a few examples of innovative practices identified within the CoE cultural routes.

Sales Location	**Innovation adoption**	**Innovative products development**
On-site sales fixed-place consumption	Vin de Saint Martin, Phoenician Route meals, Ruta de Juderias stays	Virtual reality shows (Pyrenean Iron Route), Pescatourism formulas, (Archaeological), trekking and cycling tours, mini-itineraries, short distance trajectories as in Transromanica and Phoenician Routes, Via Francigena, Iron Route Assembling diversified tourism packages as per Route des Villes d'eau and the Pyrenean Iron Route (to complement the thermal offer or to blend industrial patrimony with sculptures, museum visits**[1] and other forms of art and education)
Sales and consumption along and beyond the cultural routes' destinations	Biker tours, tour operator formulas on Transromanica for China and US, on Hansa, the Olive Tree, Legacy of Al-Andalus Routes. Assembling existing hotspots into packages across the routes	GPS clocks and flash codes for ramblers and monuments, Exhibition, cycle carrying bus (DNV). Hansa Business Days, dedicated IT / web / GIS applications for use along the Cultural Routes as per Via Regia, St Martin of Tours: long distance trajectories involving carriers, brokerage services and knowledge-intensive mobility services

Table 1. Types of innovations within the cultural routes and their SMEs

Overall, the *Study* shown that development of cultural tourism is a logical next step in developing CoE cultural routes since this type of tourism builds on the uniqueness of remote destinations, local knowledge, skills, heritage and traditions. CoE cultural routes have significant potential for cultural tourism development as well as for the promotion of economic, social and territorial cohesion in Europe. A number of cultural route partners are collaborating effectively and are producing remarkable results, particularly, at the local level. Our experts concluded that these collaborative practices could be enhanced by professionally applied network governance models and availability of funding for key skills development, capacity-building, training, networking, and cross-marketing activities.

Elements of sustainable tourism management: It is important to note that the CoE cultural routes differ not only in their thematic focus but also in their network structures, management capacities, development approaches, geographical dimensions, target groups, and quality standards of the products and services. Undoubtedly, this diversity contributes to a variety of cultural projects, products and services creation along cultural routes destinations. At the same time, these differences generate a need to adapt or develop specially-designed management tools and models that could be applied to individual routes and would reflect the uniqueness of every itinerary, while

** In case of the Pyrenean Iron Route, it can be argued that the elaboration of the Route led to a revitalization of several pedagogical centers into the Route-based cultural tourism chain. E.g. the museum of Ripoll (Catalonia, Spain) to which didactic visits are organized, and a former school for metal working in the Basque Country (Spain) where interactive scenographies in relation to metallurgy are presented. These are clear examples of how the Cultural Routes valorize European cultural values and heritage.

accounting for diversity of their characteristics. The *Study* experts concluded that such a need could be best addressed by incorporating elements of sustainable and respectful tourism to cultural routes heritage management and performance evaluation.

Sustainable development is a process that "ensures to meet the needs of the present without compromising the ability of future generations to meet their own needs", according to the Brundtland Report (1993), officially entitled as "Our Common Future" and first published by the World Commission on Environment and Development (WCED) in 1987. This definition of sustainable development implies the limits imposed by the present state of technology and social organization on the environmental resources. It also speaks to the limited capacity of the biosphere to absorb the effects of human activities.

Therefore, sustainable development is not a fixed state of harmony but rather a process of change with the major objective to satisfy human needs and aspirations while protecting natural environment and creating structures that ensure economic development of the society. The five basic principles of sustainable development, according to the Brundtland Report, are:

- Holistic planning and strategy
- Preserving essential ecological processes
- Protection of human heritage and biodiversity
- Intergenerational equity
- Balanced fairness and opportunities between nations

The CoE cultural routes have already moved a step further since the time the *Study* (2011) conclusions and recommendations were made available. Today, our cultural route managers are working along the lines of five basic principles of sustainable development improving their models of cultural heritage management, performance evaluation, and applying these principles to their individual contexts. This was made possible by a new joint project on European Cultural Routes cofounded by the Council of Europe and the European Commission, who put the financial and human resources together to advance the quality of cultural heritage management in Europe.

These new cultural heritage management models are also in line with the guidelines of the UNWTO (2003) sustainable tourism development and management practices. They focus on optimal use of environmental resources, maintaining essential ecological processes and helping to conserve natural heritage and biodiversity, respect the socio-cultural authenticity of local communities, contribute to inter-cultural understanding. They also ensure long-term economic operations while providing socio-economic benefits to all participants.

Along these lines, the *Study* also recommended the CoE cultural routes to maximise their potential in terms of digitalization, new social media and web use. These tools were suggested to be used in the form of integrated umbrella platform. The majority of the routes already established dynamic and interactive websites providing regular updates on their activities, offering interactive maps, events lists and best practice exchange (see Picture 3 for an example of interactive map). In this way the routes could seize the opportunity to develop new cultural tourism product and service offers, and to get a broader exposure to potential customers.

Picture 3. A screenshot of an interactive map on the website of the Via Regia Cultural Route of Council of Europe

The *Study* (2011) revealed a range of challenges to the CoE cultural routes environments that require further attention. These include:

- enhancing trans-national connectivity of the cultural route networks,
- development of a stronger brand image and marketing strategies,
- design/implementation of quality and sustainable tourism standards, adjusted to cultural routes environments,
- enhancing human and financial resources of the routes, and
- development of relevant (network and performance) evaluation tools.

The *Study* concluded that in order to address these challenges, and to assure that the potential of the CoE cultural routes for sustainable and inclusive growth, for responsible cultural tourism development, for promotion of cultural heritage preservation, and for economic, social and territorial cohesion in Europe is fully realized, it is important to develop a strategy for the CoE cultural routes that would include the following elements:

- better articulation of the added-value of the cultural tourism sector in general, related SMEs and their networks for economic and social development of cultural routes' destinations,
- strengthening the capacity of the cultural routes to engage effectively in local and regional development and encourage a greater professionalism in the area of cultural routes network governance,
- development of relevant cultural routes improvement strategies - at local, regional and transnational levels - built on partnerships between public authorities, cultural organizations, corporate business, SMEs, and civil society representatives,
- improved communication between and within cultural route networks especially at regional and transnational levels: successful experiences should be further exploited and disseminated,
- identification and exchange of examples of best practice and innovations between and within cultural route networks,

- development of better evaluation techniques and methodologies and their more extensive application to the Cultural Routes and their coordinating bodies, and
- addressing the issue of quality and sustainable tourism criteria development for the cultural routes

CONCLUSIONS

This paper offered an overview of the *Study on the Impact of the CoE Cultural Routes on SMEs Innovation, Competitiveness, and Clustering* (Khovanova-Rubicondo et al. 2011) that demonstrated how the need for implementing the sustainable tourism management practices is growing within the CoE cultural routes, and what mechanisms are to be put in place in order to fully incorporate these practices.

One of the breaking findings of the *Study* is that, even though founded on social and cultural principles with no particular goal to create economic benefits or raise any income, CoE cultural routes today serve as a source of innovation, small business creation, and cultural tourism products and services development.

The author of this paper is convinced that the below provided conclusions can assist cultural heritage managers and policy makers around the globe in their better understanding of socio-economic and tourism potential of world cultural heritage sites, while encouraging respectful and sustainable heritage management approaches.

Cultural route constitutes a new category of cultural good which generates an interaction between a monument in need of protection and development, and the cultural or regional context to which it must be linked in order to be fully understood and appreciated.The promotion of responsible and sustainable tourism is a logical next step in developing cultural routes in Europe and globally, since this type of tourism builds on the uniqueness of cultural destinations, local knowledge, skills, heritage and traditions.

It is also important to notice that cultural projects - such as cultural routes - are capable of not only improving economic conditions of remote destinations through income generation for local communities, but also of contributing directly to local communities' competitiveness, new employment creation, and social well-being of their citizens. Increasingly, the cultural routes also become a focal point for trans-national networking and cluster development.

Sustainable development and maintenance, respectful treatment of the environment and cultural heritage sites are crucial for successful functioning of CoE-certified and cultural itineraries/ projects and their involved SMEs around the world. Cultural routes offer an impressive mix of different products and services to their customers. They attract larger and larger number of visitors increasing by this the demand for their cultural goods and necessitating the need for related services. Yet, it is important to keep in mind that this demand for cultural goods should not overthrow the supply in a sense that physical and environmental capacities of the heritage sites would be jeopardized.

Therefore, cultural heritage should be managed in a well-balanced way to provide for continuous protection and proper maintenance of cultural heritage sites while offering access to larger audiences of visitors who come to appreciate their uniqueness.

Finally, a rapid growth in cultural and tourism destinations worldwide means that the CoE-certified cultural routes and similar projects today face the challenge to be even more competitive and quality conscious in order to attract more tourists in a global marketplace. This reconfirms the need for implementation of quality and sustainable tourism development standards along the cultural routes destinations, as well as the necessity to develop a new coherent roadmap for cooperation between similar initiatives globally.

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ISSUES TO BE ADDRESSED FOR TRANSFORMING A DIGITAL LIBRARY APPLICATION FOR EXPERTS INTO ONE FOR FINAL USERS

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KEY WORDS: IPSA digital archive, digital cultural heritage, digital cultural heritage collections, collection of illuminated manuscripts, digital humanities collections, CULTURA project, case study, different categories of users, digital library application

ABSTRACT:

This paper reports on the effort we made in adapting and opening a specialist tool, focused on illumination and designed purposely for scholars and researchers, in order to be suitable also for the general public. We describe the ongoing process we are conducting: the adaptation and the improvement of the IPSA digital archive using the results we collected after several sessions of user interviews, following suggestions of both scholars and simple users. We discuss user studies dynamics, that we consider as a loop-interaction, and the consequences that they entail upon the system design.

1. INTRODUCTION

Currently one of the most significant goals for curators and providers of digital cultural heritage collections is to increase the engagement of users and communities with digital humanities collections, and possibly to gain the interest of new user categories. To accomplish this difficult task, it is essential to draw a precise profile of the different kinds of user and to study new ways of requirements elicitation, to address the exact needs and expectations of the final users.

We carried out the research work presented in this paper using, as a case study, the *Imaginum Patavinae Scientiae Archivum* (IPSA) digital archive. IPSA makes available to scholars a collection of illuminated manuscripts (Mariani Canova, 2002), which includes botanical codices produced mainly in the Veneto region during the XIV and XV centuries (IPSA website). The IPSA archive was initially designed for a specialist public of scholars and researchers (Agosti (et al.), 2003) with specific interest in manuscripts and illuminations.

The effort to address the needs of a wider variety of users is one of the main goals of the CULTURA project (CULTURA Project website), for which IPSA has been selected as one of the representative case studies. Hence it was decided to open the collection to other categories of users, such as non-domain professional researchers, student communities and the general public. This new task required the identification of the needs, wishes and preferences of these new categories in order to define the required changes and improvements to IPSA (Agosti (et al.), 2011). To this end, we carried out an evaluation with different categories of users, comparing the requirements of professional researchers with the ones of interested general public (at the moment represented by students in related disciplines).

The efforts made to open the IPSA digital collection of illuminated manuscripts to a wider public are bringing about useful reflections and suggestions that can contribute to this field of investigation.

Section 2 briefly reports on the characteristics of interest of the digital archive that constitutes the case study. As can be seen in Section 3, interactions with both master students and professional researchers had been carried out, in order to receive valid inputs from different user categories. The suggestions received from the first interactions had been suddenly incorporated in the software application which manages the digital archive, and then tested in another evaluation opportunities, creating a fruitful loop of user interaction described in Section 4. Section 5 highlights additional issues that we faced in opening up IPSA and that constitute results that can be of general interest for curators and providers of cultural heritage collections, and Section 6 discusses on the process of extending a digital resource created for domain experts to the one for other categories of users, including the general public; the process requires a number of steps that are introduced and that represent a novel result, in fact, to our knowledge, no similar effort has been documented in the literature making no feasible for us to compare the results of our studies to other ones.

2. CHARACTERISTICS OF INTEREST OF THE DIGITAL ARCHIVE

The digital archive includes astrological and botanical manuscripts belonging to some of the most important libraries in Europe and the world.

The archive has been initially designed to meet the requirements of scholars in history of miniature that are mostly interested in analyzing images, their style, their elements and possible relations with other images belonging to different manuscripts. Because of that, the metadata included in the archive are both a description of each of those manuscripts together with

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information on the content and the provenance of each digital image of each manuscript. That makes clear that the "content" of interest for the scholars is constituted by the images. In fact the users are interested in the images ("content") rather than in the texts of the manuscripts. Further information on initial requirements of IPSA together with details of the characteristics of the interface and available functions of the software application initially designed and developed are reported in (Agosti, M. (et al.), 2012).
The manuscripts that are of interest for the CULTURA project are the 10 botanical manuscripts that are included in IPSA, because of that, the details and information on those manuscripts have been summarized in Table 1 where the author, the title, the call number, and the number of images of each manuscript are reported.

Author	Title	Call Number	Number of Images
Anonymous	Tractatus de Herbis	Paris, Bibliothèque de l'Ecole des Beaux-Arts, Masson 116	338
Nicolò Roccabonella	Liber de Simplicibus	Venezia, Biblioteca Nazionale Marciana, Lat. VI. 59	983
Macer Floridus; Serapiom; Guarnerino da Padova	De viribus herbarum; Aggregator; Herbarius	Bergamo, Biblioteca Civica Angelo Mai, MA. 592	185
Pseudo-Apuleio	De herbarum virtutibus	Padova, Biblioteca dell'Orto Botanico, Ar.26.n.1283	200
Pseudo-Apuleio	Herbarius	Firenze, Biblioteca Medicea Laurenziana, Plut. 73.41	89
Pseudo-Apuleio	Herbarius	London, British Library, Cotton Vitellius C. III	84
Pseudo-Apuleio	Herbarius	Montecassino, Archivio della Badia, Casin. 97	46
Pseudo-Apuleio	Herbarius	Wien, Osterreichische Nationalbibliothek, Codex Vidombonensis 93	132
Serapiom	Liber Agregà	London, British Library, Egerton 2020	53

Table 1. Botanical Manuscripts included in IPSA

3. USER STUDIES

Two parallel evaluations have been carried out on the IPSA digital archive. Although there were large differences between the user groups in the interest of the digital archive content and in the motivation for the interaction, the user studies highlight some common outcomes regarding the difficulties of user-driven development, which appear to be more relevant in the case of cultural heritage applications.
User requirements were elicited in two ways. Firstly, thorough interviews with professional researchers were held, both with the domain professional researchers involved in the creation of IPSA from the very beginning, and with non-domain researchers expert in the field of History of Medieval Art but not acquainted with the IPSA collection and the History of Illumination in general. All the interviews were held on an individual basis.
With regard to the student community, the organization of different trials on a group basis with IPSA was thought to be the best solution for obtaining useful input and information. The trials were held in two different moments: the first time the trial was carried out with two groups of university students in October and November 2011, the second time was in April 2012 with a different cohort of university student. The IPSA trials turned out to be a fruitful way to have a useful feedback from the students, and they helped to improve the application and its functions; the results of the trial we conducted in 2011 are mainly reported in (Ponchia, 2012). In the following we report on the additional insights we gained with trial and interviews conducted in 2012.

3.1 Professional Users

For the interaction with the professional users it was decided to involve three researchers in History of Art specialized in different domains. Because IPSA was created purposely for specialists in History of Illumination, two of the professional users chosen for the interview were scholars expert in this research area. The first one, Federica Toniolo, is Associate Professor of History of Medieval Art and History of Illumination at the University of Padua. In her career she thoroughly studied the Italian Medieval and Renaissance Illumination, particularly the Ferrara production. Her more recent studies are about illuminated manuscripts and incunabula made in Northern Italy in the XIV and XV centuries, especially choir books, and she is currently involved in the cataloguing of the illuminated medieval manuscripts of the Veneto libraries. The second researcher in History of Illumination is Silvia Fumian, Research Fellow at the University of Padua, whose research interests are about illuminated manuscripts made in Veneto in the late XIV and early XV centuries, and in Ferrara and Mantua in the XV century.
In addition, since it is essential to engage with professional users, from different domains, it was decided also to involve a researcher in History of Medieval Painting, Zuleika Murat, currently a third year Ph.D. Fellow at the University of Padua, with a thesis on the XIV century Paduan painter Guariento di Arpo. The aim of her study is to analyse the painter's catalogue, and reconstruct the connection between paintings and their original settings and functions, the typology of scattered panels, and the influence the patrons had on the choice of iconography and eventually of style. It was thought that, thanks to her different field of specialization, she could have different expectations, needs and wishes about the digital system and its functions, and that the interaction with her could foster a new original reflection on how to improve IPSA.
The interviews took place on May 2012 and were carried out on a group basis. The interaction followed a three-fold structure:

- Short introduction to present the results of the work done.
- Presentation of the new IPSA version and its functions, such as the new image search procedure in a manuscript catalogue file and the new way of creating a link between two illuminations.

- Open discussion.

It is important to note that professional researchers are already using a number of digital resources for their studies, including a prior version of the IPSA collection. The analysis of requirements could then be carried out also comparing IPSA functions with the ones of systems already available on the Web.

3.2 Master Students

Since the IPSA collection is meant to be open to general users due to its involvement in the CULTURA project, trials with other categories of users than professional ones are required in order to obtain input and information about the needs of the general public. For this reason we chose to present the IPSA system to a group of students who are specialized in other fields of the humanities, for the purpose of receiving direct comments and feedback from a significative subset of general users.

Therefore we organized two trial sessions in which students were asked to use the IPSA archive pursuing specific tasks we assigned. Every task was designed in order to verify the different user dynamics and to understand which kind of obstacles a general user can find in using a specialist tool. After the two sessions we organized a focus group during which students could discuss the whole experience underlining both positive and negative aspects of the IPSA digital archive and suggesting modifications to improve the environment, the browsing experience and the research function.

The IPSA trial that was conducted in April 2012 was developed specifically for a group composed by 25 master students majoring in History and Management of Archival and Bibliographic Heritage and in Modern Languages who were attending the course on Database and Internet held by Maristella Agosti, professor of Computer Science at the University of Padua. We chose such a sample because we considered that users who have specialization in a different field of the humanities than history of art can provide valuable contributions in the improvement of the whole environment, since even if they do not have particular interests in illumination or history of art in general, nevertheless they have a thorough knowledge and specific expertise which allow them to notice details who may have been ignored before by both art historians and computer scientists; interviewing and interacting with such a subset of users, a whole new perspective was given, allowing a significative improvement of the entire system thanks to the disclosure of new points of view.

The trial was composed by two parts that took place in April 2012 within two weeks. In each part of the trial students had to accomplish some tasks that were designed purposely to interact with the IPSA system using its specific functionalities. The trial was structured in three units:

1. **Introduction** to the IPSA archive: in this unit a specialist (a PhD student in History of art for the first trial, and a linguist for the second trial) explained some technical characteristics of the IPSA system, in order to clarify some crucial aspects such as specific terminology or normalization issues, and mostly to illustrate how to use the archive properly.
2. Description of the **tasks**: in this unit students were asked to actually use the IPSA digital archive following a series of defined assignments purposely designed in order to experience the most important IPSA functions such as research of images and manuscripts, the possibility of establishing links between two images which are considered mutually related and the browsing tool which allows the user to easily scroll the manuscript pages in order to find the required illumination.
3. Filling of a **questionnaire**, in order to obtain structured feedback: after each trial the students answered an evaluation questionnaire developed by a team of psychologists of the University of Graz who are partners of the CULTURA project (CULTURA Project website: partners). The questionnaire aimed at evaluating the interaction with the system and the acceptance of the users. The questionnaire used, first covers questions on demography, knowledge of technology, in general, and the experience with the digital collection, in particular. This is followed by two short items querying the level of support of individual and community needs/objectives by the digital collection. Subsequently, usability and user acceptance are queried. The use of standardized questionnaires provides the advantage of a sound assessment on a certain evaluation parameter, and the possibility to compare evaluation results even with other studies.

After the two trial sessions we organized a focus group with all the students who took part to the study, in order to have a wider discussion about the IPSA experience and about possible issues or suggestions. The debate about the user experience was very interesting and it highlighted several modifications that can be made in order to improve the system both from a graphic and a technical point of view. The students observations underlined the importance of working on simplification, in order to make a specialist tool more involving for a general public. It is a fact that this kind of audience needs to be charmed and intrigued by an agreeable environment whose functioning is clear and immediate. Simple users generally do not have particular interests in illumination or manuscript but they can find fascinating to browse a beautiful collection if the entire experience is made easy and smooth.

3.3 Closed Loop Development

A frequent interaction with users during their evaluation of IPSA allowed a very fast evolution of some features as consequence of the user difficulties we observed. During the evaluations the principal causes of problems were:

- Low performance on rendering the pages.
- Difficulties on maintaining the context during the navigation.
- Difficulties on understanding some elements of the interface.

These observations on a very closed evaluation-development loop produced a number of enhancements on the IPSA system and interface that were made directly available to users during the second round of evaluation.

First of all, the list of images of a work evolved from a simple wall of all images, very heavy to render and to explore, to a partial wall of twenty images, very fast to render. The user can request more blocks of images clicking on a button that activates an AJAX request, and it is still very fast to render, without losing the current context. As a (currently) last step, on the top of the wall has been added a textual drop-down list of all images of the work, ordered by page; selecting one element from the list, the user can jump to the block containing the thumbnail of the desired image, as depicted in Figure 1. At this stage of interaction with the IPSA application, the user can request to examine a specific image; the result of this request is the presentation of all the metadata of the image together with the possibility of seeing the complete image as in Figure 2.

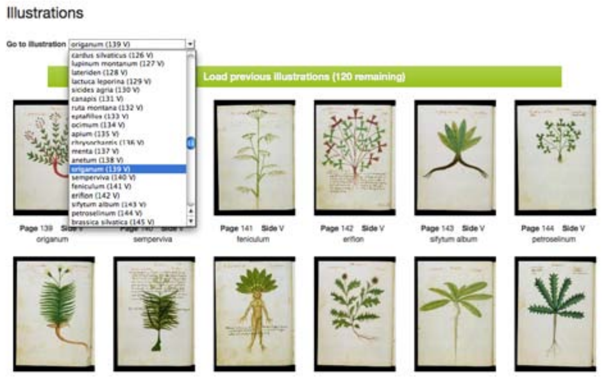

Figure 1: The textual drop-down list of all images of the work, ordered by page, and the block containing the thumbnail of the desired image are shown.

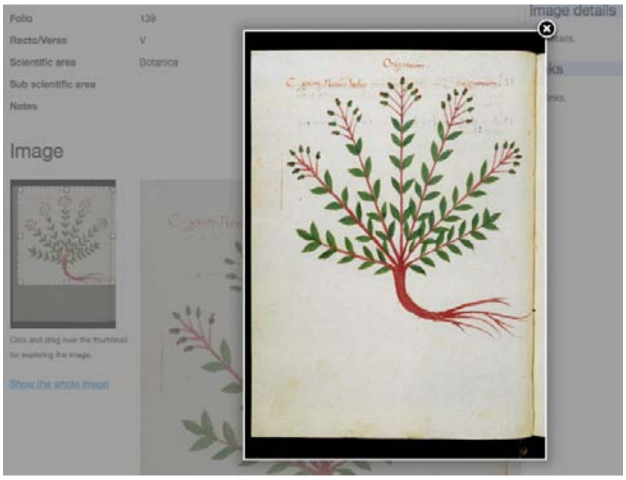

Figure 2: Presentation of all the metadata of the image of interest together with the presentation of the complete image.

For reducing the loss of context when the user navigates from the page of a work, to a page of an image, and back to the work, the position in the wall of images is maintained during all the navigation in the same work and its images. Using the experience acquired on the page of a work, almost the same interface has been implemented for the wall of images of the result of a search of images.

The process of the creation of a link between images was very difficult to understand because of the simple, mostly textual, interface available. This operation is a multi-step process in which the user, starting from an image, can navigate and use all IPSA features for searching the ending-point image of the link. During all the process, on the top of the page, is showed a box with the status of the operation. Following the observations of the user, this box has been enlarged and now it includes the thumbnails of the selected images, some help text, and large very explicative buttons for completing the link, or for deleting the operation. Even the navigation has been modified a little bit: now after the starting of the link creation, i.e. after selecting the first image, the user is moved to the advanced search for images, with the form totally empty, and still no results, as shown in Figure 3, where the query - "rosa alba" - has been inserted in the form but the system has not been asked yet to process it. This has been evaluated by the users as a very comfortable, understandable and useful type of interaction for this situation. When the user selects the image to link, among the ones retrieved through the advanced search, the system copies the image on the screen, and gives the possibility to the user to complete the link, as it is shown in Figure 4.

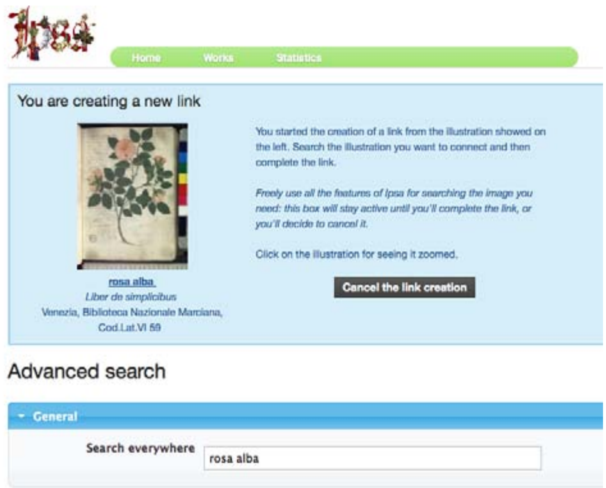

Figure 3: The user selects an image from which to create a link, and he can conduct an advanced search to find the related one.

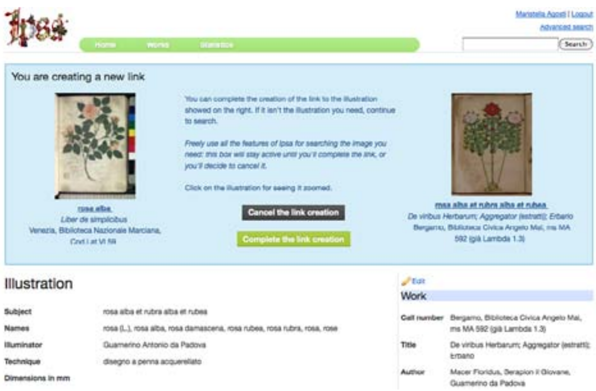

Figure 4: The presentation to the user of the image to relate to the initial one.

The choice of modifying the user interface while carrying out the evaluation showed to be successful. Students felt that their comments and suggestions were taken into account, and where increasingly motivated in interacting more deeply with the IPSA digital archive. Nonetheless, it was crucial to incorporate the input given by the students without losing contact with the professional researchers needs. That is why it was decided to carry out a new in-depth interaction with professional users. We gave to the IPSA user studies a loop shape. The circle we created starts from the professional users, it goes through the general public filter and it comes back to the original target. Thanks to this passages the IPSA archive takes in account both needs of researchers and simple users, creating an environment that can be used as a professional resource and at the same time can be browsed by general users as a catalogue of beautiful images.

4. CONSIDERATIONS ON USERS INTERACTION

The choice of implementing the required changes while carrying out the evaluation had an additional motivation. In fact, one of the most striking thing that came out from the discussion results, is that for both groups of users, it was difficult to give suggestions on a large scale.

In the case of the professional researchers, although the interview aimed at fostering their reflection on their general research needs, that CULTURA wants to address with new specific tools, the focus was on improvements of minor importance. For example, Fumian, Murat and Toniolo said that the links presented in the catalogue file of an illumination should be shown in a different way: actually, it is difficult to distinguish the manuscript library and call number from the text annotated by the user. So the interviewees suggested that the manuscript call number should be justified, while the text annotated by the user should be a flush left italic text, preceded with the heading “Notes” and written in a different colour (e.g. dark green). Another example is that the three researchers paid a lot of attention to the written instructions, and suggested many changes to the text, often small refinements (e.g. “Start a new link” should be replace by “Create a new link”). It emerges clearly that they felt more self-confident in giving small advices concerning details of minor relevance, as if it was easier for them to imagine little improvements rather than picture big changes and new functions that could address their research needs.

During the interviews, we thus stimulate reflections of general requirements, asking general questions such as:

- Which kind of functions do you think can help you in your research?
- How could technology most meaningfully assist you in your research process?
- What kind of information and/or visualisations should the research environment make accessible in order to support your research process?

The answers were quite general. It was also noted that when the three interviewees tried to suggest improvements and additions to IPSA they took inspiration from tools they already are confident with, such as ARTstor (ARTstor website). For example, Toniolo said that she would like to have the possibility to create a folder where she can save her searches and decide which research results can be shared with other users and with whom, a functionality that already exists in ARTstor. This underlines one more time that lack of imagination and influence of previous models can be an obstacle in user requirements elicitation. So the interviews with the professional researchers prompted the need to find and develop new ways of stimulating users’ imagination and a deeper reflection on their needs and wishes.

The same considerations apply to the student cohort. Most of the written comments collected through the questionnaires were about the interface layout (e.g. the number of characters in the text fields or the positioning of images) and the perceived easiness of use, which improved between the two trials thanks to the closed loop development approach. This tendency of concentrating on details was evident also during the discussion of the focus group. Comments regarded the position on screen of images, their dimension, the length of descriptive texts, and so on. These results are inline with considerations about the “bike-shed effect”, which is a well-known drawback in computer software design (Fogel, 2005): there seems to be an inverse proportionality between the relevance of a feature and the time spent discussing it. Again, the choice of implementing directly the required functions was in the direction of reducing this effect, although it is normal that non-expert users concentrate on the interface and its details because they feel they do not have the competences for providing useful comments on the architectural and methodological levels.

Notwithstanding these considerations, there was a major difference between students and professional researchers for one IPSA function. It regarded their experience with the search tools. While specialists do not have problems accessing the digital content, thanks to the their deep knowledge of the domain, students sometimes had difficulties in carrying out search tasks. Difficulties were partially related to their lack of knowledge about illuminated manuscripts, because it is not trivial to understand how search results are ranked, which are the most useful search fields and how to address relevance of retrieved items.

5. ADDITIONAL ISSUES IN OPENING UP IPSA

At present the IPSA data are stored using a PostgreSQL relational database application (PostgreSQL website) and managed using also a Lucene index (Lucene website). In the near future some data will be managed by a documentation management system and by an annotation management system. So IPSA is already a system composed by different heterogeneous subsystems internally integrated.

The involvement in the CULTURA project and the goal of extending the categories of users including the general public, opened the door to various problems of integration with external systems, mainly for allowing such systems to retrieve and use data from IPSA, both metadata and images. The main problem here is not technical, but cultural and administrative.

Most of the images included in the IPSA collection have been obtained with the grant for using them in the IPSA application, but not for publicly distributing them, or for transmitting them to an external system on which we cannot guarantee an appropriate use. It is in fact a problem of copyright on the images, which will be addressed asking the copyright holders an extension of the grants for freely distributing at least a degraded water-marked version of the original image. As a sort of digital rights management (DRM) protection, the water-mark could even include the name of the user, or of the system, that obtained the image from IPSA.

Similar problems of copyright/privacy could apply to the metadata that the IPSA users add to the collection, in form of annotations, links, or other types of content that need intellectual protection. In this case the choice will probably be left to the user itself, that can assign different levels of sharing to his contributions. For example, he could create one or more groups of colleagues or students, and share his contents to the group(s) he prefers. Alternatively he could release his material as public.

Moving to the technical parts, at present IPSA has some interaction points with external systems through the exposition of some web services. Given the heterogeneity of the systems involved, the exposed services needed simplicity and independence from the hardware and software platform, and from the specific programming language. So we decided to implement them as RESTful (REpresentational State Transfer) web services, as any system capable of sending a simple HTTP (Hypertext Transfer Protocol) request to a specific URL (Uniform Resource Locator) could use them (World Wide Web Consortium website). At present services are available for obtaining the metadata of all the works in XML format (World Wide Web Consortium website), the metadata of a single work in XML format, and the thumbnails of a single work bundled in a file in zip format. The names of the thumbnail files inside the zip file are built using the unique identifier of the image that can be retrieved from the corresponding XML metadata.

Each service need HTTP authentication for being accessed. The authentication is necessary for assuring that the user (or system) owns the expected level of privileges for invoking the service and obtaining the requested data. For example, only a user with administrative privileges can obtain the full set of metadata.

As you can see, in this case the administrative problems are more challenging than the technical solutions. When we own the necessary grants on the images, we can adopt a similar approach for having them accessible from external systems. Moreover we could impose limitations on the maximum image resolution, on the specific work, or even on the specific image to the users and systems using the services.

Providing such services we can expect the following scenario:

1. An external system authenticates on the IPSA services.
2. It requests the list of the works it can access in XML format.
3. Using that list, it chooses or iterates on the work of interest, requiring the metadata of each work.
4. Using that metadata, it can request the bundle of thumbnails, or, in the future, the single water-marked image.

6. DISCUSSION

The process of extending a digital resource created for domain experts to other categories of users, including the general public, requires a number of steps. These steps are related either to additional user requirements that have to be harmonized with the existing system or to technological aspects that have to be addressed to improve the user experience with cultural heritage collections. Figure 5 represents this process as a spiral, going from a specific application developed for a focused group of expert users to a general purpose system able to raise the interest of a larger audience.

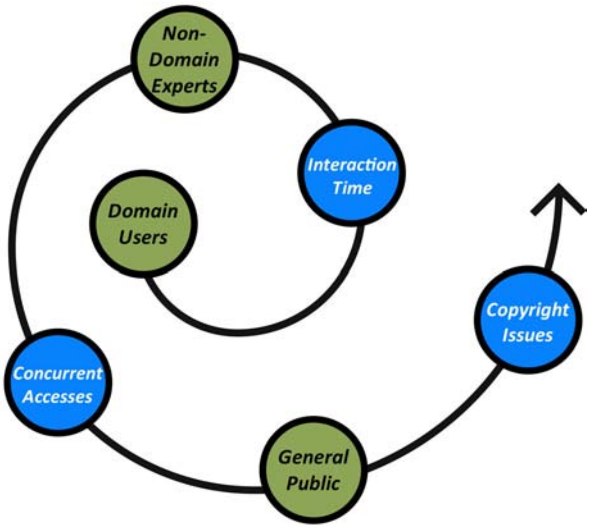

Figure 5: A representation of the different steps of the process to extend cultural heritage resources from domain experts to the general public.

In this paper we describe some aspects of this ongoing process, which we are developing with a user-centred approach. The choice of addressing the technological issues during the user evaluation, providing participants with a prompt feedback on their requirements, helped us to partially overcome the problems of recollecting input on the usability of the IPSA digital archive. Some questions still remain to be addressed, as the ones related to copyright management previously described. The next steps will regard the integration of IPSA digital archive within the CULTURA portal, supported by a continuous validation based on user studies.

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THE ARAB IMAGE FOUNDATION: COLLECTING, STUDYING AND PRESERVING PHOTOGRAPHS FROM THE MIDDLE EAST AND NORTH AFRICA

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KEYWORDS: Arab Image Foundation, Arab world, Chadirji, modern cultural heritage, Madani, Middle East, networks, photography, preservation, training, Zaatari

ABSTRACT:

The Arab Image Foundation (AIF) has been collecting, studying and preserving photographs from the Middle East and North Africa since 1997. It runs curatorial and research projects, and activities related to photograph preservation. Fifteen years after its creation, the AIF's archive holds over 600,000 images, including complete collections entrusted by photographers such as Hashem el Madani (Lebanon) or Kamil and Rifaat Chadirji (Iraq). Such collections require sustained efforts in terms of archiving, documenting and digitizing. In addition to the care of its own collection, the AIF's current preservation programs include the Middle East Photograph Preservation Initiative (MEPPI), which seeks to identify and offer training to significant photographic collections in a region where expertise in conservation and preservation is all too often absent. The AIF is also a member of the Modern Heritage Observatory, a coalition which campaigns for the preservation of modern cultural heritage through the creation of a regional network of individuals and institutions committed to its cause.

1. COLLECTING PHOTOGRAPHS

Established in Beirut in 1997 by a group of prominent Arab photographers, video artists and curators, the Arab Image Foundation is a non-profit organization dedicated to the collection, study and preservation of photography and other related visual material from the Middle East, North Africa, and the Arab diaspora.
Fifteen years after its creation, the Arab Image Foundation's archive today holds over 600,000 photographs. Over the years, AIF members have gathered photographic material from a diverse range of sources: from families to professional studios, and photographers to collectors.
The Arab Image Foundation works to make its collection accessible to the public through a wide spectrum of activities, including site-specific exhibitions, publications, videos and an online image database. It seeks to encourage critical approaches to the reading and interpretation of photographs.
The contents of the AIF collection represent both the foundation's central preservation mandate and the specific research interests of its members. The artists, writers, filmmakers and historians affiliated with the AIF have, to date, initiated research projects in Lebanon, Syria, Palestine, Jordan, Egypt, Morocco, Iraq, Iran, Mexico, Argentina and Senegal. The result is a dynamic and at times idiosyncratic collection that not merely illustrates the history of photography in the region but rather situates a wealth of different photographic practices within a complex context of social, economic, political and cultural factors.
Authored by professionals, amateurs and anonymous photographers alike, the collection's images cover a wide breadth of genres and styles – including documentary, historical, reportage, industrial and advertising photography. The diverse range of subjects includes architecture, family and studio portraits, fine art, landscapes, still life and nudes.
In addition to expanding the AIF's collection, the research projects make valuable contributions to the study of photography in the region by collecting information on photographers: their biographies and the conditions informing their practice. Inevitably, the research projects raise questions about how images are used, and their relationship to notions such as identity, history and memory. The AIF's approach to assembling a collection differs from that of more traditional historians, conservators or curators in that the process is primarily led by the critical and creative work of artists.
Through the efforts of the AIF, the photographic works of Van Leo (Egypt), Latif el Ani (Iraq) and Hashem el Madani (Lebanon) have been introduced to an international audience. Prints and negatives from these and other collections selected for their artistic and historical value are scanned in high resolution and made accessible via the AIF's internal database, with approximately 20,000 of these images also available online on www.fai.org.lb. The standards used for the digitization and e-preservation of the AIF archive have been developed by the AIF in the course of the last 15 years. Several consultants helped develop the AIF's digitization guidelines. In particular, Franziska Frey, today Head of Preservation and Digital Imaging Services at the Harvard Library, reviewed and edited the guidelines in 2011. The photos are documented in the AIF database with extensive metadata available.

Since its inception, the AIF has produced fifteen exhibitions and seven publications in partnership with international museums, galleries and cultural institutions. The collection has also proved an invaluable resource for artists' projects, curatorial initiatives and academic research. Its premises are open to the public daily and include a unique library dedicated to photography and extensive research facilities.

2. STUDYING PHOTOGRAPHS

2.1. The Madani collection

One of the AIF's long-term areas of study is the Madani Project, featuring the work of studio photographer Hashem el Madani (1928-). The entire archive of Madani's Studio Shehrazade is taken as study material to understand the complex relationship tying a studio photographer to his working space, his equipment and tools, economy, and aesthetics, and further explores his ties to his clients, society, and the city in general.

Initiated by artist Akram Zaatari and the Arab Image Foundation, the project reflects, on the one hand, Zaatari's interest in living situations and configurations as objects of study that bear witness to modern traditions and complex social relationships, and, on the other, the AIF's commitment to preserving, indexing and studying photographic collections from the Arab world. The Madani Project comprises a series of thematic exhibitions, publications, and videos centered on the photographer and his work.
Through this project, the Studio Shehrazade archive is gradually being identified, detailed, and preserved by the AIF, and, with over 100,000 negatives, is one of the AIF's largest collections.

Hashem el Madani was born in Saida, but of Saudi Arabian descent. In 1947, Madani travelled to Palestine seeking employment, and began working in Haifa as an assistant to a Jewish immigrant photographer named Katz. He returned to Saida a year later at the outbreak of the events of 1948. In Saida, Madani bought his first 35mm camera for 200 Lira, and began to work as an itinerant photographer. He would walk in the city offering his services to shop owners and passers-by. At the same time, he transformed a space in his parents' home into a studio. By 1952 Madani had raised enough money to buy new equipment and rent a studio of his own in the same building as Cinema Shehrazade in Riad El Solh street, thereby giving the studio its name.
Madani's archive sheds light on the life of a city during half a century of dramatic sociopolitical change. However, the studio was most active over the course of the 1950s, photographing residents of Saida – families, individuals, shop owners and workers – and as such providing a portrait of the city from this important historical period.

Syrian resistant
Saida, Lebanon, 1970s
Hashem el Madani, Studio Shehrazade
Copyright © Arab Image Foundation

From 2004 to 2007, the AIF, with the support of the Prince Claus Fund, was able to process and archive over 100,000 negatives, and digitize a selection of 30,000. Following this effort, a 2010 grant from Bank America's Art Conservation Project allowed the AIF to preserve and digitize further the collection. A portion of the digitized images is available on the AIF website, at www.fai.org.lb.
Hashem el Madani's archive is the AIF's longest running research project to date. So far, work on Madani's archive has produced two books, three exhibitions and two videos. One exhibition in particular, titled "Itinerary", is a permanent installation dating back to 2007, when the AIF installed 60 photographs in shops scattered throughout the old city of Saida. These portraits by Madani of shop owners standing next to their stores were each exhibited in the exact locations of the original stores – of which some are still standing, and of which others have taken on very different forms. This interactive installation encourages the public to engage with the new shop owners and, if curious, to discover Saida through its oral history.

2.2. The Chadirji collection

The Chadirji collection is one of the most recent additions to the AIF archive. It was entrusted to the AIF by Rifaat Chadirji, a renowned Iraqi architect and photographer and comprises his own archive, as well as that of his father, Kamil Chadirji. The latter was a journalist, political activist, and an avid photographer who documented social change and injustices through his lens. He sought to record the disappearing traditional Iraq and to document the poverty that existed therein. K. Chadirji's collection of 1,200 images had already been through a rigorous process of archiving before arriving at the Arab Image Foundation in the spring of 2012. The collection, which spans his work in various countries including Iraq, Lebanon, Syria and Iran, is dated chronologically and classified according to subject matter. It features images of prominent personalities in Iraqi society, intellectual gatherings and social life in addition to self-portraits, from the early 1920s to the 1960s.

Shoemaker
Baghdad, Iraq, 1928
Kamil Chadirji
Copyright © Arab Image Foundation

Rifaat Chadirji, meanwhile, is one of the most prominent architects in the Arab world. Despite living through a turbulent political context – paying the price with an imprisonment of 20 months in Baghdad – he was prolific as an artist and photographer during the second half of the 20th century, both within Iraq and abroad. He is an honorary member of the Royal Institute of British Architects and was previously a Laureate of the Aga Khan Award for Architecture. With regard to his architectural style, R. Chadirji has stated that he 'set out to learn from traditional architecture and to achieve a synthesis between traditional forms and [the] inevitable advent of modern technology' (Morgan and Naylor, 1987). Not unlike his father, Rifaat Chadirji sought to document social change in Iraq through his photographs, and has argued that whilst Kamil's photograph bear witness to a slow and peaceful change in Iraqi society, his own images record an 'accelerated, sometimes violent […] in some aspects very sophisticated and ordered and in most cases chaotic, vulgar and sinister change' (Chadirji, unpublished essay). R. Chadirji's collection at the AIF numbers around 60,000 negatives, featuring his personal photography in addition to photographic documentation of all his architectural projects. Each project – whether completed or merely proposed – was given a unique number, in chronological order. Since arriving at the AIF, these projects have been identified, ordered and documented, ready to be cleaned and processed. The negatives of R. Chadirji's personal photography projects had mostly already been numbered by date and classified by categories that reflect Rifaat's anthropological and sociological approach to photography. The Chadirji collection is today of historical importance and value for researchers and the AIF is actively engaged in fundraising efforts in order to be able to process, document and digitize the collection further. All of these efforts will be conducted under the kind supervision of Mr Rifaat Chadirji.

Contact print titled "Al-Azim"
Baghdad, Iraq, 1978
Rifaat Chadirji
Copyright © Arab Image Foundation

3. PRESERVING PHOTOGRAPHS

The AIF's collection is held in a purpose-built cool storage room located in the foundation's headquarters in Beirut. The facility is an integral part of the foundation's preservation strategy, which adheres to international standards for the conservation of photographic materials. Both climate-controlled and fireproof, the space limits the exposure of photographs to light and variable temperatures. The core staff of the AIF have been trained in working with all of the different photographic materials that are acquired and managed by the foundation. The collection features a broad range of photographic processes, including glass-plate negatives, albumen prints, stereographs, lantern slides, hand-colored prints, gelatin silver prints and negatives on acetate and nitrate film. Prints and negatives are cleaned, numbered, digitized and stored in conditions appropriate to their physical state. The foundation uses a range of housing materials that meet PAT (Photographic Activity Test) standards. Some are imported, while others are specially commissioned from local craftsmen.

In addition to focusing on the preservation of its own archive, the AIF has implemented several successful projects aimed at preserving photographic heritage throughout the Mediterranean and across the Arab world. Its two current preservation projects are the Middle East Photograph Preservation Initiative (MEPPI) and the Modern Heritage Observatory (MoHO). These projects allow the AIF to extend its preservation ambitions and offer its expertise to other regional collections.

3.1. The Middle East Photograph Preservation Initiative (MEPPI)

The MEPPI program was initiated jointly by the Arab Image Foundation and two world leaders in photograph conservation, Nora Kennedy and Debra Hess Norris. Kennedy is the Fairchild Conservator of Photographs at the Metropolitan Museum of Art, while Hess Norris chairs the Art Conservation department at the University of Delaware. The ambitious MEPPI program was designed with the goal of identifying, assessing and training significant photograph collections in the Middle East and North Africa upon observing that the conservation and preservation of photography in the region is still in its infancy despite the existence of many invaluable photograph collections. This is partly due to the fact that national libraries and archives, for example, do not uniformly include photographs with their accessioned collections of documents, books, maps, and other materials. Collecting has mostly taken place at colleges, universities, private organizations, ministries of culture, and exists on an individual level. Often, even when these collections exist, they are not always recognized or valued and may not be provided with the staff and funding necessary for their adequate care.

The MEPPI project began in 2009 with a Getty Foundation-funded pilot workshop, during which participants from 10 collections from Egypt, Iran, Jordan and Lebanon were exposed to the fundamental concepts of photograph preservation, followed by concrete applications of theories and techniques. The curriculum included introductions to the technical history of photography, image formation and deterioration, degradation mechanisms and causes. Emphasis was put on hands-on demonstrations and *practica*. At the conclusion of the workshop, participants developed individual and joint preservation goals, and remained in contact with each other and with their instructors through the platform of the online MEPPI blog.

Following the success of the pilot workshop, the project was renewed with funding from the Andrew W. Mellon Foundation and a partnership with the Getty Conservation Institute. The new MEPPI cycle began in 2011 and is programmed for three years.

The new and improved MEPPI began with a process of identifying significant photograph holdings in the Arab world. Prior to the MEPPI survey, several institutions had endeavored to locate regional collections of all sizes (among others the Institute for Palestine Studies in Ramallah, CULTNAT in Cairo, or the Qatar Unified Imaging Project…) but the collected information is still scattered and not yet readily available to the public and scholars.

Three researchers were selected to conduct the MEPPI survey, and each was assigned a region. Jean-Gabriel Leturcq, a French scholar and PhD researcher, with experience at the Digital Center for the Conservation of Libyan Archives, researched and identified over 120 collections in the Arab Peninsula. Dr Mark Westmoreland, professor of anthropology at the American University of Cairo, identified around 100 collections in Egypt and the Levant – research in Egypt being made possible through collaboration with CULTNAT's program "Photographic Memory of Egypt". Finally, Marie Moignard, independent researcher and curator based in Paris and specializing in the history of Moroccan photography, identified over 50 collections in North Africa. This important research will allow the AIF to build and share a regional directory of photograph collections.

Other research components of MEPPI included the development of an English-Arabic-French glossary of photograph conservation terms that will facilitate the Arabic translation of academic publications on photograph preservation.

During its new cycle, MEPPI also proposes three photograph preservation courses over three years. The first MEPPI course, MEPPI Beirut 2011, was attended by 18 participants from leading photograph collections of the Greater Middle East, including national archives and libraries, museums, press agencies, and universities in Egypt, Iraq, Iran, Jordan, Lebanon, Morocco, Palestine and Syria.[*] Participants and instructors engaged in theoretical and practical sessions covering the identification, preservation and display of photographic materials, both analog and digital. Participants were provided with preservation toolkits and sample housing materials. Selected participants were also provided with state-of-the-art environment monitoring data-loggers, to gather data on storage conditions. The workshop included collection visits to the American University of Beirut, the Arab Image Foundation, and Studio Shehrazade. A public talk at the Beirut Art Center addressed the critical challenges and best practices associated with digital print preservation.

MEPPI Beirut 2011 participants
Tram Vo
Copyright © J. Paul Getty Trust

Participants in MEPPI Beirut 2011 have enthusiastically acknowledged the value of the MEPPI courses, both for the skills they gained and the sensitivity they acquired in matters of preservation and shared cultural heritage. Participants were inspired to work together to strengthen the preservation of photographic materials in the Arab world. The 18 participants then engaged in the distance-learning phase of the course, which is coordinated by the Getty Conservation Institute. During this period, assignments ranged from assessing a collection to preparing an emergency plan. Participants disseminated information collected from MEPPI within their institutions and beyond, some even giving public talks on photograph preservation, such as Clare Davies and Ibrahim Abdel-fattah at the Contemporary Image Collective in Cairo, in February 2012. Participants met again as a group in September 2012 to share their accomplishments and to discuss challenges faced. One of the participants had volunteered to host the group for the final meeting, which was held at the National Library of Morocco (Bibliothèque Nationale du Royaume du Maroc). Meanwhile, the selection process is ongoing for the MEPPI Abu Dhabi 2012 course scheduled to run from the 11-19 November 2012 at New York University in Abu Dhabi. The course will provide training to a second group of photograph collections from the Middle East and North Africa A third MEPPI course will take place in the fall of 2013. By the end of the three courses, approximately 50 individuals responsible for photograph collections in Middle East institutions will have received supervised preservation training, and a strong network of like-minded individuals and institutions will have been established.

3.2. The Modern Heritage Observatory (MoHO)

The second major preservation project undertaken by the Arab Image Foundation in 2012 is the Modern Heritage Observatory (MoHO), a coalition formed by the AIF and three regional partners: the Arab Center for Architecture (ACA), the Association for Arabic Music (Irab) and the Cinémathèque de Tanger (CDT). The MoHO initiative, funded by the European Commission and in parts by the Heinrich Böll Foundation, aims to advocate for the preservation of modern cultural heritage – with an emphasis on photography, music, architecture, video and film – in the Middle East and North Africa. The project's remit was borne out of an absence of sound cultural governance in the Middle East and North Africa, where the preservation of cultural heritage depends almost entirely on the initiative of individuals and a few cultural heritage organizations.

While the partners, and other cultural heritage actors, have managed to gather and preserve important collections that would otherwise have been lost, they struggle for sustainability in a political context characterized by outdated legal frameworks and weak political commitment to cultural heritage. They are determined to mobilise their efforts in order to impact policies. The key constraints addressed by the Modern Heritage Observatory initiative include the lack of systematic coordination and exchange of expertise among cultural heritage actors; the absence of a platform uniting advocacy efforts calling for policy reform and legal protection; the lack of technical and financial support from local actors; and a lack of access to, and participation in, cultural heritage by the general public.

Through the creation of a network for professional bodies from the Middle East and North Africa, the project promotes the exchange of experience, pooling of expertise, and the elaboration of strategies for joint advocacy initiatives. By organizing a variety of activities including trainings, national

[*] Participating institutions were, from Egypt, the Grand Egyptian Museum and the Qasr el Doubara Institute for Historical Research; from Iran, an independent researcher; from Iraq, the Iraq National Library and Archive and Photographic Memory; from Jordan, the Department of Antiquities, the National Library of Jordan, and the Royal Protocol; from Lebanon, the American University of Beirut, An-nahar, the Arab Image Foundation, the Daralhayat Information Center, and the Fouad Debbas Collection; from Morocco, Bibliothèque Générale et Archives de Tetouan, Bibliothèque Nationale du Royaume du Maroc; from Palestine News and Information Agency, WAFA; from Syria, the City of Aleppo Archive

and regional meetings, film screenings, exhibitions and the publishing of articles, the Modern Heritage Observatory will contribute to making modern cultural heritage of the Arab world more extensively preserved and widely accessible.

In March and June 2012, the Arab Image Foundation hosted networking meetings bringing together actors in cultural heritage preservation in Lebanon. Over 30 participants attended the first networking meeting, which served to inaugurate the MoHO initiative. The meeting focused on identifying shared needs and concerns among the actors of cultural heritage in Lebanon, and aimed at building the basis of the network and discussing common goals and objectives. Building on the concerns identified, participants were then asked to fill in a survey assessing their needs and detailing their expectations from the network. Accordingly, the second networking meeting addressed two critical topics that had emerged from participants' answers: emergency preparedness, and the need for a common visibility and communication strategy. As emergency plans are a key tool for archive repositories, network members decided on creating working groups, where those holding comparably-sized archives of similar media will together develop emergency salvage plans.

MoHO national networking meeting #1
Beirut, March 2012
Walid Sader

In addition, an online platform is being launched by the AIF and its MoHO partners that will facilitate the network members' discussion and provide a space to share their opinions and concerns with regard to emergency procedures and other cultural heritage issues. The platform, to be launched in the fall of 2012, will be a reference point for cultural heritage information and news from the Middle East and North Africa.

During 2012-3, four other national networking meetings will be hosted by the AIF, each focusing on a specific theme or issue voted on by the MoHO network members, such as lobbying strategies, policy propositions, and trainings. Similarly, the Cinémathèque de Tanger will host two networking meetings in Morocco, with similar goals and methods. Additionally, two regional networking meetings will be organized by the Heinrich Böll Foundation, allowing for the discussion to be opened up to regional actors of cultural heritage preservation.

To ensure the sustainability of the project's impact, MoHO also includes a strong educational component. Through the Modern Heritage Observatory, the AIF was able to send an archivist to be trained at the Musée Nicéphore Niépce in France, and to gain skills and knowledge in archiving and preservation. Staff members of other partners in MoHO are also benefiting from technical training in the physical and digital preservation of their archives. In return, the AIF is offers free training in the digitization of photography to a number of institutions requiring such technical skills. To date, these services have allowed several collections representatives in Lebanon, Palestine and Iran to receive one-on-one technical training in digitization.

Future project activities will include collective lobbying for better regional policies. In particular, 2013 will witness the publication of policy briefing papers by Modern Heritage Observatory members, which will discuss recommendations for policy reform and practices related to the preservation and protection of cultural heritage.

CONCLUSION

The development of new preservation and educational activities at the Arab Image Foundation in recent years has established a blueprint for the large community of individuals and institutions committed to the preservation of photographic heritage.

Remaining challenges for the preservation of photographic heritage in the Arab world are two-fold. Firstly, to campaign for the commitment of local and regional agencies to draw up strong policies for the protection of modern cultural heritage; secondly, to secure local and regional funding for preservation projects that are, currently, for the most part, funded externally.

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Immersive cultural experience through innovative multimedia applications:
The History of Monserrate Palace in Sintra (Portugal) presented by Virtual Agents

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KEYWORDS: Cultural Heritage, Monserrate Palace, Multimedia Applications, Multimodal, Embodied Conversational Agents, Multidisciplinary Approach, Immersive and Interactive experience

ABSTRACT:

We are currently in the process of making a series of interconnected multimedia applications, in order to value and enliven the monuments of Sintra, Portugal - classified by Unesco as World Heritage site in 1995. This national project, *Fala Comigo* (Talk2Me), aspires to present new contents, not only to scholars but also to an unlimited number of visitors, and thus achieve a social, cultural, educational and civic mission. As an interdisciplinary project, the historians generate the content, while the engineers and technicians design content-driven multimedia applications. In this phase, our case study is the Monserrate Palace, a revivalist building of the 19th century. These applications profoundly rely on a balance between renewed heritage contents, a rigorous scientific approach and stunning designs. We encounter innovative multimodal ways of visitor-application interaction, mainly with the addition of virtual agents that works as guide assistants with educational purposes.

1 Introduction

Nowadays, Cultural Heritage has become a vastly discussed subject. It has become a dominant topic in a wide variety of areas, such as numerous systems, applications and serious games, which have been designed while keeping in mind several specific circumstances. Like no other area, Cultural Heritage demands a multidisciplinary organization and effort in order to achieve its crucial goal – *user learning*.

Without a solid foundation of contents, Cultural Heritage applications are just attractive pieces of software with no real educational use for the visitor. On the other hand, without a coherent and structured scientific approach, the technological systems will not meet the demanding requirements for this type of media. Moreover, if on top of that, we add an absolute necessity for that unique eye-candy factor, we can see the mist forming very quickly. The success of a *Cultural Heritage* system deeply relies on challenging balance between these three core areas.

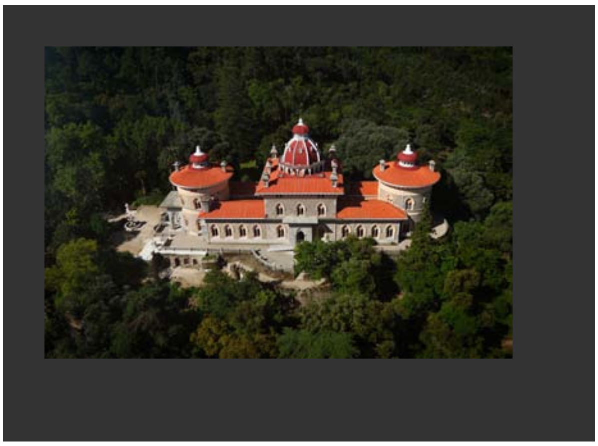
To achieve this, there must be a commitment to producing renewed content, developed through with discourses aimed at different age groups and appealing to an awareness of how important it is to preserve artistic heritage. These studies must be presented according to the modern lines of dissemination, based on emerging technologies that capture the attention of these new audiences, establishing a framework that allows for both the dissemination and the enjoyment of heritage.

The creation of Human Computer Interaction (HCI) systems in a Cultural Heritage scenario has been our project's main focus in these past few years. Systems, applications and even serious games have been developed. However, something was clearly missing – a unique connection between the system and the visitor. Since the current results were displeasing, the field of Embodied Conversational Agents and Integrated Dialogue Systems became the solution. Nevertheless, finding new multimodal ways of human-computer interaction, that would amaze any visitor, is demanding. Using the world-renowned game engine Unity3D, a reusable embodied conversational agent framework to be used in Cultural Heritage scenarios, was created.

Throughout this paper, every decision and action that made possible the creation of a conversational agent based module, which core focus is to interrelate with the user, will be explained.

2 Monserrate Palace: A brief history

The Monserrate Palace, inserted in the striking landscape of Sintra, is now the target of an integrated restoration program. After almost half a century in relinquishment, degradation was gradually taking over the historic building.



The original construction was due to a wealthy English merchant Gerard Devisme, who in mid-eighteenth century leased the property to the Family Mello e Castro. A few miles from Lisbon, Sintra, with its mild climate, was a much sought-after place by nobles and wealthy burghers for building exquisite and charming summerhouses. Between the sumptuousness of the highlands and the Atlantic Ocean, values such as the picturesque and the sublime of the landscape, attracted the most sensitive spirits in the time of Romanticism. Devisme choose a neo-Gothic program for this country house in Monserrate. Reminiscing a small medieval castle, the cylindrical forms surmounted with merlons flank the longitudinal body of the construction.

Nonetheless, the international notoriety of Monserrate would be attained due to its famous tenant, the writer William Beckford, who inhabited the house between 1794 and 1799. Furthermore, Lord Byron also perpetuates these events in his important poetic work, Childe Harold's Pilgrimage (1812-1818). Beckford's departure a few years later and the occupation by French's troops, during the Napoleonic wars (1807-1814), left the property abandoned and the house in ruins.

D. Ferdinand of Saxe-Coburg-Gotha-Koháry, a German prince that in 1836 became king of Portugal by marrying the Queen Maria II, deeply desired the property. At Sintra’s mountaintop, the King had just started the construction of his own private palace, where a former convent once existed. The idea of extending his dominions was particularly attractive.

However, it was Francis Cook (1817-1901), a wealthy British textile trader, who acquired the property in 1860, after having rented it a few years before. Cook immediately delineates a plan to reformulate the ruined Gothic Revival mansion, turning it in his summer residence. To this end, he hires the architect James Thomas Knowles (1806-1884), who surely received strict orders to respect the pre-existing structure. Knowles creates a decorative interior and exterior, in revivalist-like taste, where Italian and Oriental references abound (Metcalf, 1980). The new palace, suggestively called “Beckford Hill”, was reborn with plastic quotes of the Alhambra in Granada, the palaces of Venice and the dome of Florence Cathedral, among others. Francis Cook became an important art collector and, with pieces of great artistic value he decorated not only the house, but also the magnificent gardens in which he had planted with species from different sources.

The property remained in possession of the family for three generations. However the destructive effects caused by World War I in Cook, Son & Co., led the grandson of Francis Cook to place the property up for sale in 1928. Due to the 1929’s economic crisis, it was not easy to find someone with enough purchasing power to acquire the estate. With the Second World War, the maintenance of the property became unbearable for the Cooks. Francis Ferdinand, grandson of the first Cook, would eventually auction off the precious content of the palace in 1946, selling the property to an individual in the following year.

Although the Portuguese State was presented with this noteworthy possibility, it was decided that Monserrate would not be purchased, even knowing its importance and artistic history, only for acquiring the property two years later. However, the lack of a defined utilization program ran the palace to a progressive deterioration. It was already after the year 2000 that the renovation process began. Primarily with the roofing structure, followed by all main infrastructures, the restoration works have been developed by Parks of Sintra - Monte da Lua, the responsible for the management of the monument ever since. These profound contributions awarded PSML with "Best Public Project Renewal" prize in 2010, by Tourism of Portugal. Nowadays, the works take place inside the palace, with the recovery of several rooms - a painstaking process of restoration of the wonderful stucco lining walls and ceilings. Even under the “open for works” policy, those who come to discover the palace are not disappointed. On the contrary, it stimulates a greater flow of visitors, who can actually witness the work process.

3 Promoting and disseminating cultural heritage through a multimedia experience

In order to promote the historical and artistic facet of Monserrate Place and the current ongoing rehabilitation campaign, a striving multimedia project was devised.

Furthermore, we envisioned a fresh alternative way of raising the interest of the visitors, by conveying a new, distinctive and enriching experience when learning the history of the monument.

3.1 A multidisciplinary approach

Making use of pioneering technologies, a multidisciplinary team composed of art historians, curators, graphic designers and engineers crafted an interactive museology solution committed in renewing the knowledge base of this historic building.

For this proposes, we invested in the artistic and historical research, looking for new contents. After a preliminary phase of content selection, treatment and aggregation with the already known content foundations, it was necessary to consider a unique articulation, which targeted dissemination via attractive multimedia procedures. The requirements differ from those perceived in the presentation of traditional dépliants, or in basic texts for audio guides.

Thus, under the temporal perspective of the monument (in the national and international context), and without losing sight of who were the main actors (owners and artists), it was intended to show the successive steps of the palace: the two major campaigns of works; the architectural and decorative influences, the richness and apparatus of the interiors; the degradation that ensued when the palace was unoccupied, and ultimately, the restoration as a work in progress, looking to show how the work of art is fragile and the importance of conservation.

With the themes defined and assigned with suggestive names for the multimedia systems, it was necessary to determine the technical solutions that best served the educational purposes of each one. This was an interesting combination of ideas among historians and technicians in order to maximize results for the creation of a high quality cultural product.

3.2 Immersion and Interaction

The use of three-dimensional representations presents itself as an excellent visual translation of bi-dimensional images, such as architectural drawings. These 3D representations are much more enlightening to the general public. Their reading and understanding are immediate, serving as a framework for other iconographic sources, such as prints, drawings or photographs. While spaces were recreated, it also presented the possibility of inserting historical characters.

The introduction of embodied conversational agents harvests a particular empathy in the public, since they provide the necessary link for achieving the main goal with this type of creation, which is promoting maximum interaction by establishing a spoken dialogue where the agent answers the visitor's questions in real time. Thus, together with the immersive experience, the visitor is encouraged to interact, acquiring an active assertiveness that favors the assimilation of knowledge.

In the field of immersion and interaction, serious games have been taking an active role in the dissemination of cultural heritage (Anderson, Mcloughlin, Liarokapis, Peters, Panagiotis, De Freitas, 2010) (Neto, Silva, Neto, Pereira, Fernandes, 2011). They are an excellent way of transmitting knowledge through playing. This mechanism operates in information transferring, taking on a specific didactic form that presents very positive results. Also, with the motivation generated by a game, the user takes a significant commitment that is unparalleled in a multimedia application only with informative purposes. Given these characteristics, our set of complementary multimedia applications and serious games follow these principles.

3.3 Design and usability for visitor's engagement

The success of these applications profoundly relies in the combination of three dissimilar factors: an **attractive and striking design**, impressing the visitor and enhancing the cultural experience; a **defined pedagogic orientation**, correctly steering the user throughout the learning process; and **innovative multimodal ways of human-computer interaction**, increasing user immersion and engagement (Zyda, 2005).

A spot-on combination and balance between these core factors is decisive for a correct user engagement. Plus, an ideal hardware support choice is tremendously important as well, since the chosen supports need to accommodate all the features offered by the applications. Some applications may demand large multi-touch screens since they were thought for a wider crowd interaction, when others may only require smaller screens, as they were considered for single-user engagement.

The mobile solution is ambivalent. It serves the objectives for those who like to use their own device, even when other fixed supports are available. Additionally, in museums and monuments where the number of simultaneous visitors can be so high that kiosks are not a sensible option, the mobile presents itself as the ideal solution.

Lastly, due to increasingly smaller budgets in this area, the multimedia applications need to answer a series of basic requirements. Besides the topics already mentioned, we had to take into account fundamental questions of how these applications might be quickly reused, modified and corrected. Thus, it is intended that if required, the monuments' managers can quickly make updates and those who design and architect the systems can reuse their work in other contexts.

Therefore, these projects were designed to be stimulating, challenging the user constantly, while never disregarding the important cultural and educational aspect.

4 Monserrate's Applications: Type, Themes and Technical Solutions

Following the principles described in the previous section, we created a complete historical set of seven multimedia applications. Enhancing content accessibility allows for the most fundamental objective of a Cultural Heritage application – *user learning.* By using complementary cultural contents, we designed simple yet memorable interfaces, where the contents are well conveyed and absorbed.

These applications are grouped by three distinctive types: Multi-touch Informative, Multi-touch Interactive and Serious games (table 1).

4.1 Multi-touch Informative Applications

Looking to the first type – Multi-touch Informative Applications – we have two main themes. Firstly, the *Lords of Monserrate*, which is dedicated to the different owners of the palace estate throughout the centuries. Here, we had to take into account the diverse genealogical aspects of all the lords and nobleman that inhabited Monserrate. The volume of information demanded a coherent approach and a strong inter-relation of all the elements, leading to the creation of a cultural-content network. Moreover, the information about one individual is connected with the other applications. Using content-based steering, the visitor seamlessly crosses through all the elements that concern a specific individual.

As for the other Informative app, *The Restoration*, ilustrates the evolution of the degradation phase and the following recovery process, through a mobile augmented reality (AR) application. This solution presented itself as the most promising to effectively show the visitor the declination and all the steps towards full restoration. As each room of the palace has a distinct covering plaster with a specific decorative pattern, these are used as the AR image-target. An image-target is a specific pre-assigned pattern that, when recognized by the mobile device camera, triggers an action. Thus, the camera is able to identify each plaster design and therefore acknowledge the room that the visitor is in. This generates specific information and images about that room and its restoration process on the mobile phone.

4.2 Multi-touch Interactive Applications

Regarding the second type – Multi-touch Interactive Applications – the motto was to promote the visitors' discovering process. With *Monserrate: Two Palaces,* the visitor will be able to interact with the different architectural solutions. For this purpose, we used two distinct 3D models. The first model, created in 3DStudioMax, was made using architectural drawings of the primitive construction dated to the 18th century. The actual palace model resulted from a laser-scanning procedure done by the Portuguese company ArtScan, with some further simplifications to be game-engine-ready (Neto, Neto, Silva, 2011).

For the treatment of the interiors – *At the time of Cook Family*, we used a magnificent collection of old photographs taken when the Cook family lived in the Palace. These are hidden beneath current pictures of each room, and user is invited to discover them through an image discovery swipe procedure. The revelation is exciting, enabling the visitor to realize how the palace was richly decorated with works of art of considerable value.
The beauty of the landscape and architecture of Monserrate always attracted painters, designers, photographers and filmmakers. Displaying this iconographic wealth to the visitor is the purpose of *Monserrate through Images*, where the four-finger touch procedures (the user can pitch, swipe, zoom in and out) enhance the appreciation of the detail of each image.

4.3 Serious Games

Finally, in the Serious Game type section two distinctive games were created. First, *What you know about Monserrate?,* a quiz-based game, where the visitor tests the knowledge acquired throughout the exhibit. A virtual agent presents a short promotional video with all the fundamental cultural information, asking the visitor four questions afterwards. This interactive dialogue is an engaging way of accessing if the informational was correctly conveyed.
Lastly, we are currently producing an immersive serious game with a complex plot, were the usage of embodied conversational agents establishes new boundaries. Based on the story of the palace, the fictional plot centres on a group of precious works of art purchased by Cook, and which have now disappeared without a trace. The aim is for players to find out where these pieces have been hidden in the palace gardens. Players subtly receive cultural information and success depends on the amount of knowledge learnt about the history of the monument.

All these applications have, as common denominator, multimodal ways of interaction. As the visitor interacts with the multimedia contents of the applications, they can also interact with the conversational agent. Merging these two concepts can improve the global visiting experience and play an important role in the learning process. When interacting, the visitor can use a multi-touch based input or simple and intuitive voice commands. In particular scenarios, the ECA can help and guide through, always ready to respond to current-domain questions that may surface. In parallel, it is possible to offer an innovative experience where the ECA's knowledge domain changes according to the specific application scene. Handling the various core features, as for example the facial and body animations, complex behaviour and personality and the real-time interactive dialogue are the results of a complex and on-going research process. We had to design, architect, and produce a set of various tools to be able to explore the use of virtual agents in multimedia applications for Cultural Heritage.

5 Using Embodied Conversational Agents ECAs

When approaching this problem it was necessary to take into account our founding requirements, capacities, objectives and the preceding works done in this area of knowledge. The Cultural Heritage paradigm fairly differs from the usual scenarios where Embodied Conversational Agents are commonly used. However, the better way to convey cultural and educational knowledge to the visitor is to use a human-like historical character, equipped with the complete vital informational of a heritage site.

Figure 2. Historical virtual characters

As mentioned before, this information has to be previously aggregated and restructured to be usable in a pioneering multimedia setup. Without specifically crafted cultural contents and proper virtual agent usage, the cultural heritage message will not be passed correctly. As we can see, there are many challenges to overcome in order to successfully provide a new and immersive experience to the visitor.

Although a virtual agent plays a decisive role in this multimedia scenario, the users' discovering process must also be somewhat independent. The visitor needs to interact freely, while knowing that the agent is always there to support them, even when it is not visible.
Following these concepts, we defined a structured approach to explore the benefits of using a virtual agent in a multimedia application for Cultural Heritage:

- **Non-interactive animation sequences must be brief and clear to engage the visitors.**

This is the case of most opening scenes where, typically, the user knows slight or nothing about the topic in hand. The agent must be efficient on conveying the primary cultural contents, trying to raise the interest of the visitor swiftly. If the visitor is not defied, the probabilities of abandoning the application are awfully high. This is the most critical stage of the interaction.

- **The Embodied Conversational Agent model and animations must be realistic enough.**

When engaging the virtual agent in a conversation, the user should be confortable and captivated. Only with realism can a user immersion in a real-time conversation be accomplished. If the animations are poorly made or the agent's 3D model has no quality, the interaction will not have the same followthrough effect that it should. A great animation library to mimic numerous human movements in a convincing way was a key requirement. This process grasps three main cores:

face movements, full-body animations and complex human emotions. Without appropriately developing these three features, real-time interaction will be a poorer experience for the visitor. By adding the Question & Answer component and the Behavioural module, it is possible to create Agents with a specific personality. However, that personality is only believable if all parts involved work accordingly, mainly the emotions and body animations.

- **The Embodied Conversational Agent must be context-aware at all times**

The last important thing to attend is the agent's knowledge base, already mentioned in the previous topic. Instead of creating a global Question & Answer system, which is a valid option but only in restrict domains, it is far more effective to design several dissimilar QA modules, to serve each section of the application. By doing this, the ECA can straightforwardly access and retrieve the correct answer more efficiently. Otherwise, the system would probably overload when trying to obtain the answer in a larger knowledge base.

Moreover, this bears another positive consequence: by separating the modules, the navigational system is profoundly altered. This means that it is easier to go from one application to the other, without the hassle of going back and repeating content. Therefore, every application scene has a specific context locally and globally. As the visitor may pass from one application to another, the virtual agent must know, at all times, what the visitor has seen before to proper explain the cultural contents presented in that current scene.

6 An innovative HCI system

Facing the challenges described in the preceding section, we had to come up with an innovative *Human Computer Interaction* (HCI) system built in a modular approach specifically designed to assist the visitor in the course of a Cultural Heritage exhibit. In order to achieve this ambition, we developed an Embodied Conversational Agent Framework – ECA Framework.

This framework allows the creation, configuration and usage of virtual agents throughout various kinds of multimedia applications. Based on a spoken dialogue system, an *Automatic Speech Recognition* (ASR), *Text-to-Speech* (TTS) engines, a *Language Interpretation*, *VHML Processing*, *Question & Answer* and *Behavior* modules are used. These essential features have very different roles in the global virtual agent framework procedure, but they all work together to accomplish realistic facial and body animations, as well as complex behavior and disposition.

The ASR engine – Audimus (Meinedo, Caseiro, Neto, Trancoso, 2003): – is responsible for the multimodality of interaction that we endowed the system with. This engine actively collects all the voice-input commands of the visitor.

The TTS engine – Dixi (Paulo, Oliveira, 2002) – generates an audio file with phonetic and temporal tags. The phonetic tags are transformed into visemes, which are used to generate the agent's facial animations, allowing a proper and realistic form of communication between the agent and the visitor.

When a voice-input is received by Audimus, the system has to analyze and process it in order to produce a valid follow-through action. We created a *Language Interpretation module* formed by several natural language processing techniques to do exactly that.

Furthermore, we have a *Question & Answer* module(Neto, Cassaca, Viveiros, Mourao, 2006) functioning as a domain knowledge datacenter. Stored here is every question and possible answer in agent's sphere of expertise.

The behavior module regulates and generates the personality and major traits of the ECA. Our future work will focus on perfecting this module, turning it into a more dynamic process.

For standardization and reuse purposes, Virtual Human Markup Language (VMHL) is used to create the animation timeline for the ECA.

Finally the game engine Unity3D, where the input is received and the output rendered, visually supports the system. With this base architecture, we can achieve real time interaction, extensive cultural domain knowledge and easy dialogue usability.

7 Conclusions

In conclusion, it is necessary to highlight the current high demand for promoting Cultural Heritage. There is a firm belief that for a proper and attractive transfer of cultural information, the development of multimedia applications that heavily rely on realistic Embodied Conversational Agents is mandatory. This is an on-going research project, since in the past the delivery of the cultural message was compromised due to poor design and simplistic agents.

Therefore, the goal is to design thoroughly structured applications that are able to capture the visitor's attention, by the pleasing aesthetics of the application's design and the excitement generated by a multi-modal interaction with the Agent, whether by spoken language or multi-touch interfaces.

Even though the work is currently in an experimental phase, the multimedia applications of the Monserrate Palace already register an important impact among the public. Since the palace lost its entire artistic endowment, the applications constitute a new attraction and a source of entertainment for the visitors. The games are the most utilized applications, mostly by more than one person at the same time.

These interfaces create an immersive experience for the users, in different themes under specific historical settings, conveying cultural programs planned under a new didactic and technological perspective.

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Appendix

Application Name	Type	Themes	Main Technical Solutions	Hardware Support
Lords of Monserrate *Monserrate: Two Palaces*	Multi-touch Informative Multi-touch Interactive	Owners over time Evolution of architectural solutions	Cultural content network 3D model interaction	Multi-touch kiosk Multi-touch table
At the time of Cook Family *Monserrate through Images*	Multi-touch Interactive Multi-touch Interactive	Interior decoration of the palace Monserrate revisited by artists	Image discovery swipe Multi-touch image interaction	Multi-touch kiosk Multi-touch table
The Restoration *What you know about Monserrate?*	Multi-touch Informative Game - Quiz	Degradation and recovery General History of Monserrate	Augmented Reality Interactive Dialogue	Mobile devices Multi-touch kiosk
The Treasure of Monserrate	Immersive Game	General History of Monserrate and his owners	Context sensitive storyline	Multi-touch kiosk

Table 1. Multimedia Applications for Monserrate Palace - Connection between historical themes, technical solutions and support hardware.

ISLAMIC MANUSCRIPT COLLECTIONS ON THE WEB: AN EVALUATION OF THE USER INTERFACES

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KEY WORDS: Evaluation, Digital Library, Islamic Manuscripts, User Interface

ABSTRACT:

This paper presents a survey conducted to provide an overview of the functions and features of digital library user interfaces within the Islamic manuscript context. Based on Internet and bibliographical keyword search, the survey identifies 49 digital libraries that contain Islamic manuscript collections. The findings illustrate varying patterns for browsing, searching, navigation, and page-viewing systems as well as uncommon yet relevant tools and features offered by the interfaces for digital libraries.

1. INTRODUCTION

Being both cultural artifacts and literary documents, Islamic manuscripts (IM) have been extremely valuable for various disciplines including art history, sociology, anthropology, archaeology as well as comparative literature. These manuscripts cover a wide area of research by the very definition of the word 'Islamic', not only as a faith but in the sense of cultural, intellectual and material outcomes of the whole Islamic Civilization. As a primary source, the IMs present the literary, cultural and material history of the Islamic Civilization in three main Islamic languages – Arabic, Persian and Turkish (Riedel, 2010). In the past twenty years, there has been an increasing effort in the digitization of these artifacts, which is followed by the dissemination of this content over the internet through digital libraries (DL). However, the questions of 'why' and 'what' of the IMs should be archived/preserved/presented in digital are two fundamental questions that are still being discussed. These questions are highly relevant to design since the 'what' and the 'why' directly affect the 'how' which is the design of the digital application. A detailed study on 'what' and 'why' within the context of digital being of Islamic Manuscripts is beyond the scope of this paper and will be discussed in another publication.

In studies on user interfaces of DLs, various aspects of the interface design have been researched and evaluated. These investigations include searching and navigation (Baldacci (et al.), 1999; Oliveira (et al.), 1999; Marchionini (et al.), 1998), design (Thong (et al.), 1981; Fox (et al.) 1993) and presentation of information (Oliveira (et al.), 1999; Marchionini (et al.), 1998; Hill (et al.), 2000); user interaction, customization and authentication (Dorner (et al.), 2003). Majority of the research in evaluation of the DLs focus on usability studies (Xie, 2006) rather than the functions and features that the user interfaces offer. For usability evaluation, a number of different criteria have been suggested such as learnability, memorability, low error rates (Nielsen, 1993; Kling (et al.), 1994), effectiveness and efficiency (Jeng, 2005). To have an overview of the current state of the user interfaces, a different kind of investigation on DLs is necessary. This study is motivated by the need for research to explore how the Islamic Manuscripts are (re)presented in the digital libraries and what the interface design provides to the users of these DLs.

In this paper, we report on an overall analysis of the functions and features of the user interfaces of DLs containing Islamic manuscripts. The paper is structured as follows. The Introduction is Section 1. In Section 2, we explain the methodology. In Section 3, we present the findings of the survey including evaluation of the interfaces in terms of browsing, searching, page viewing and navigation, as well as supplementary features and tools that the interface provides.

Figure 1: An illustrated Islamic Manuscript, Zubdat–al Tewarikh (The Essence of Histories) in Museum of Turkish and Islamic Arts, Istanbul Turkey.

2. METHODOLOGY

To review the Islamic manuscripts on the web, we carried out a survey which recorded the online applications related to the Islamic manuscripts. The selection of the samples for the survey was undertaken in March 2012 and was based on Internet and bibliographic research (e.g. articles in journals and conference proceedings) on the subject. The initial focus of the survey was limited only to illustrated manuscripts. Due to insufficient number of samples, the scope of the survey is widened to include Islamic manuscripts in general. Therefore, the Internet search was performed using the main keywords such as "Islamic manuscripts", "illustrated manuscripts", "illuminated manuscripts", "digital library", "online library", "virtual museum", "online museum" as well as the associated keywords including "Turkish manuscripts", "Arabic manuscripts", "Persian manuscripts", "Islamic painting", "miniature painting" and the like.

A preliminary review was performed on the user interfaces of the identified DLs to determine the functions of the user interfaces to be analysed. In addition to repeating patterns of functions, interesting or innovative features of the DLs were also identified. Then, a matrix is constructed that contains a list of functions and features and a list of DLs in columns and in rows, respectively. After construction of this matrix, the DLs are further examined with a specific focus on these aspects.

3. FINDINGS

In this study, we have identified 59 currently available online applications that are providing access to digitized content of IM collections. 10 of these were not considered as DL but as exhibition, museum or collection catalogues displaying some select preview images of the manuscripts. A full list of identified DLs and their links can be found in the Appendix.

3.1 Browsing

By visual inspection, we have identified four different techniques that the DLs have implemented for browsing the collection. These browsing techniques include the use of searching, providing a list of items, a sortable list of items, and filterable list of items. Searching can also be considered as a browsing technique. However, it can be said that this method is the most inefficient way for browsing a collection. Although it does not seem to be a preferable method, 4 out of 49 DLs use this method.
Approximately half of the examined DLs (22 out of 49) provide a fixed list of items in their collection mostly including the title and the author. In case of large number of items, the list is paginated rather than infinite scrolling. Two more improved techniques that the DLs utilize for browsing is to make the list of items sortable or filterable based on various criteria such as author, date, subject, genre, geography or language. Of the 49 DLs that are examined, some (15) prefer the sortable list of items while few (8) utilize a filtering system that allows better controls and richer interaction for browsing (See Figure 2).

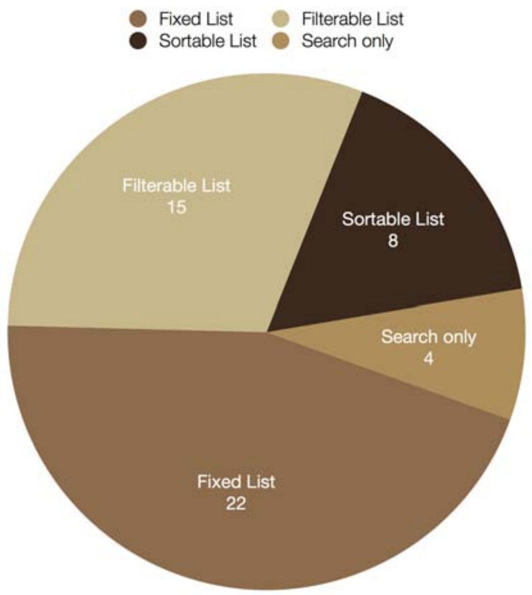

Figure 2: Distribution of browsing techniques in 49 DLs

Another point to consider for the browsing interface is the use of thumbnail images in the list. Less than half of the DLs (20 out of 49) provide a thumbnail image of the manuscripts in the list of items. Although most of the manuscripts do not contain any print title on their covers to recognize, the visual information (e.g colour, texture, size, and shape of the manuscript cover) conveyed through the thumbnail image assists in distinguishing the items in the collection.

3.2 Searching

A large majority of the DLs for Islamic manuscripts, 40 out of 49, offer keyword search only in the metadata to find items in library while 6 DLs do not provide a searching feature at all. A small number of DLs we identified, 2 out of 49, provide partial text search option in addition to metadata search. This feature is achieved by including the transcribed (in some cases translated) content of front matter (incipit, basmala, etc.), back matter (excipit, colophon), and content headings of manuscript text into the search database (See appendix, item #11 and #25). From 49 DLs that is examined, only one provides the feature of full text search. It enables users to search both within the modern Arabic transcription and within the English translation of the text. (See appendix item #1). (See Figure 3)

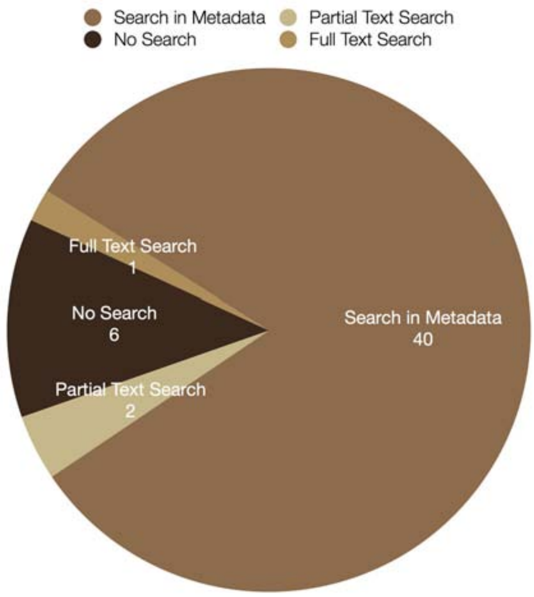

Figure 3: Searching systems in 49 DLs

3.3 The Page-viewing Interface

3.3.1 Overview of the Manuscript: Being able to get an overview of a manuscript is an effective way for browsing purposes. In a large number of DLs (30 out of 49), this need is addressed by displaying the pages of the manuscripts as thumbnail images. Among these 30 DLs that provide a document overview, two thirds of the DLs (20) display all the pages of the manuscript in the same window. Users can scroll through the thumbnails to see all the content of the manuscript. While, the remaining 10 DLs present the document overview in a paginated fashion, i.e. 5 or 10 folios per page. It is important to note, however, that a considerable number of DLs (19) do not support the document overview feature at all.

Figure 4: User interface of The Walters Museum, Baltimore Islamic Manuscripts Collection. (Displaying document overview in thumbnails, download as pdf, add to collection, share in social media and add tags features)

3.3.2 The Layout: Among the DLs in this survey, we have identified four different types of layouts for the page-viewing interface. Type 1 can be called as One-page Single Image Display which shows one page of the manuscript as a single image file. Type 2, Two-Page Single Image Display, is the two-page version of the former. This shows two pages of the manuscript as a single image file. Type 3, One-page Scroll Display contains a page of the manuscript as a single image similar to Type 1. However, in Type 3 the pages can be scrolled horizontally or vertically for smoother interaction than that of the Type 1. The most advanced layout is Type 4, the Book-like Display, which shows each page of the manuscript as a separate image in a book-like layout. This type includes both the Flash-based page-flip viewing interfaces and the conventional HTML interfaces.

The way that the DLs present the manuscripts through these interfaces varies. Although most of the DLs, 32 out of 49, use a single layout type for exhibiting the manuscripts, a notable amount of DLs (14) offer the option for users to choose from multiple layouts. The remaining 3 DLs do not provide an interface for viewing the manuscripts; instead they only give a download link to a PDF of the manuscript.

3.3.3 Page Navigation: From the 46 page-viewing interfaces, we have identified three main navigation techniques that are most commonly used. Technique 1 uses buttons to go next and previous pages with increments by 1. Technique 2 allows jumping directly to a desired page number either by manually entering the value, by selecting from the number from a drop down list, or by using a horizontal slider. Technique 3 utilizes the document overview and enables user to jump to a desired page by selecting the thumbnail of that page. Technique 1 provides liner navigation though the pages while Technique 2 and Technique 3 provide a non-linear navigation. A vast majority of the DLs (41 out of 46) employ a combination of these navigation techniques in the page-viewing interface. 38 out of 41 DLs use Techniques 1 and 2 simultaneously while 24 out of 41 provides the option for the users to choose among the techniques 1, 2 and 3 in the same interface.

In addition to these common navigation techniques, we have also identified two different ways for enabling page navigation. First technique is jumping to a page using the content headings of the manuscript. 5 out of 38 of the DLs offer this technique. Second is using a real-like representation of an open book where users can see the sides of the pages underneath the open pages. By hovering and clicking on a page, users can navigate within the manuscript. This technique is based on an open-source book reader by Internet Archive and used by 4 out of 38 DLs.

3.3.4 Zoom Type: Two different zoom types are identified, i.e. high-detailed zoom and open larger image. For most of the DLs, the zooming seems to be considered as a significant feature of the interface since 30 out of 49 DLs provide a high-detailed zoom option. While, 8 DLs out of 49 allow users to see only a relatively larger image opened in the same or in a new window upon clicking on the image or a button. Interestingly, a considerable number of DLs (11) does not offer any type of zoom or enlarged image of the page, although being able to zoom is an important need for inspecting manuscripts. Page-viewing interfaces of 35 DLs (out of 49) do not provide the option to rotate the page of a manuscript. Among the 14 DLs which provide rotation, almost all of them (13) provide rotating with 90 increments in clockwise or counter-clockwise direction. The rotation feature of the remaining one offers a more detailed control by enabling to rotate the page by 1° increments.

Figure 5: User interface of Princeton University, Islamic Manuscripts Collection. (Navigation by content headings and clicking to real-like representation of a page in an open book.)

3.3.5 Full-screen Viewing: Another function identified in the interfaces of DLs is the option to explore the content in full screen. Full-screen feature removes the distractions and unnecessary items from the page and also enables the user to see the content in a larger screen by hiding the interface elements of the browsers. Among the 49 DLs, only 13 of them provide a full screen option for the page viewing interface, although presenting the content in full-screen is highly beneficial for a more focused reading and researching experience.

3.4 Supplementary Features and Tools

In terms of supplementary tools for users, the following features have been found in the 49 DLs: download option for full content of the manuscript (14), download a selected page of the manuscript (3), compare two pages of the same or another manuscript side by side (2), copy the permanent URL of a manuscript in the collection for referencing (19) or permanent URL of a specific page in a manuscript (2), add manuscripts to a personal collection for easy access (10), create annotations on a page (2), manipulate the brightness and contrast of the image (1), request reproduction rights and licenses (3), use magnifying glass for detailed inspection of a certain area of the image (1), export citation of the manuscript (2), provide starting and ending sentences of the manuscripts in the description (2), and store clipped images from the manuscript in a clipboard (2).

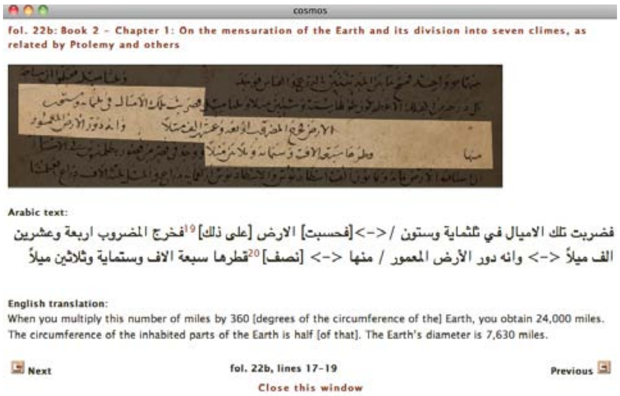

Figure 7: Displaying the Arabic text and English translation of the selected line in The Book of Curiosities – University of Oxford Library.

As for sharing, we have identified three different patterns to allow sharing: share via email only (3), share via social media (3) and share via both email and social media (9). Among these, there are two types of sharing the manuscript. The first one is to share the link or an image of a manuscript (10). The other is to share a specific page (3) of the manuscript. Moreover, another feature identified for sharing is to provide an HTML code for embedding a widget containing the manuscript to another website (1).

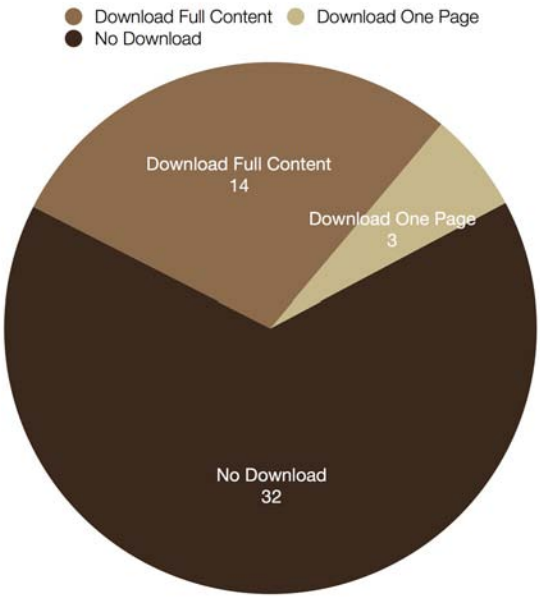

Figure 6: Options for downloading a manuscript in 49 DLs.

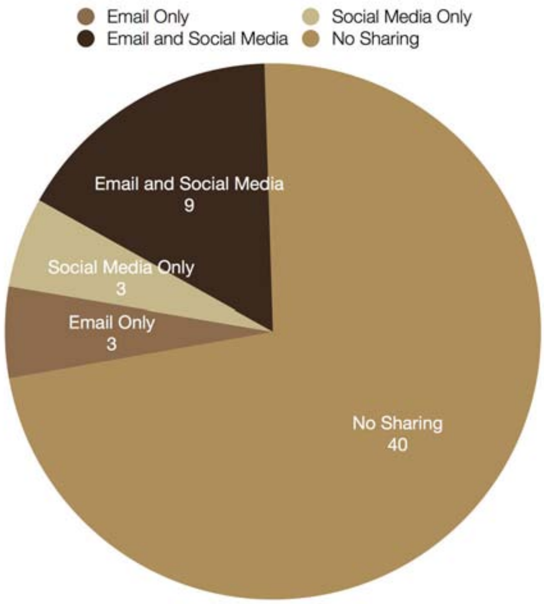

Figure 8: Options for sharing a manuscript in 49 DLs.

In terms of providing contextual information about the manuscripts, the most common feature is to display a short descriptive text about the manuscript. One of the unique features observed in this category is to provide users the translation and transcription of the manuscript as well as explanations about diagrams and illustrations with a mouse over interaction (1). Among the other features related to the contextual information are giving external links related to the manuscript (1), having a glossary (1), and providing direct links to certain pages of the manuscript within the description (1).

Use of user-generated content (UGC) is relatively rare among the DLs in this study. The identified features within the context of UGC are to post public or private comments on the manuscripts (4), to display ratings provided by the users about a manuscript (2) and lastly to add tags to a manuscript (2).

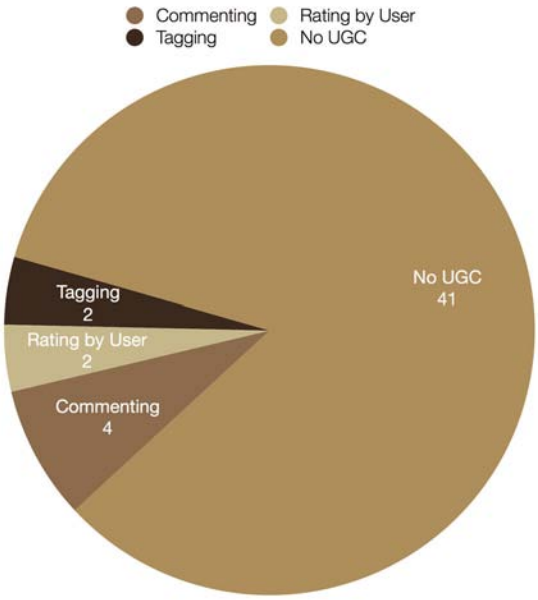

Figure 9: Use of User-generated Content (UGC) in 49 DLs.

4. CONLCLUSION

In this paper, we have identified 49 digital libraries that present digitized collections of Islamic manuscripts and evaluated the functions and features their user interfaces. A very limited number of DLs seems to consider the specific qualities of the manuscripts in the design of their interfaces. Firstly, a vast majority of the Islamic manuscripts use Arabic script but the most of the DLs do not address to this in their design. For example, the lack of full or partial text search, typing for searching in Arabic script, a virtual Arabic keyboard for different Islamic languages, transliteration of the Arabic script to Latin character set. Secondly, some of the manuscripts are illustrated and these illustrations/paintings are of high importance both from the point of view of visual culture and art history. Utilizing additional features and tools for the illustrated manuscripts would facilitate the users to better examine and provide an enriched experience about these manuscripts.

In addition, the interfaces of most of the DLs do not seem to follow the recent trends and developments in the web user interface design. Some of these trends and developments are using HTML5 and Web 2.0; connecting with social media; sharing and networking possibilities; gathering and publishing user-generated content; mobile device compatibility and using responsive design systems.

Based on the findings, it can be concluded that there is need for further research and development in terms of the interface design for DLs in this context. The direction of further research might be towards the study of the specific qualities of the Islamic manuscripts, conducting user needs analysis (i.e. determining various user groups and getting their input into the design) and incorporating new techniques and technologies for the design and implementation. This would provide more useful and effective ways to utilize these cultural artifacts in the digital domain through richer interfaces and smoother interactions.

After this analysis of how the IMs presented, the focus of our future research will be on why and what of the IMs should be represented in digital domain. Moreover, we are considering sharing the results of this research with the DLs that are included in this study. The feedback would be highly significant and create valuable discussions from various points of views.

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7. APPENDIX

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http://cosmos.bodley.ox.ac.uk
2 Harvard University, Islamic Heritage Project (IHP)
http://ocp.hul.harvard.edu/ihp/manuscripts.html
3 Princeton University, Islamic Manuscripts Collection
http://library.princeton.edu/projects/islamic/subject.html

4 Cambridge University, Shahnama Digital Index
http://shahnama.caret.cam.ac.uk/new/jnama/page/
5 Shahnama Project, Princeton University
http://www.princeton.edu/~shahnama/
6 Islamic Manuscripts Collections, University of Leipzig. Project for the Cataloguing and Digitising of 55 Islamic Manuscripts.
http://www.islamic-manuscripts.net/content/below/index.xml?lang=en
7 Bayerische Staatsbibliothek München, Collection of Manuscripts in different Oriental and east Asian languages
http://www.bsb-muenchen.de/Orientalische_und_ostasiatisch.316.0.html
8 Bibliothèque Nationale de France (BNF), Manuscrits en Arabe
http://gallica.bnf.fr/Search?ArianeWireIndex=index&f_typedoc=manuscrits&q=arabe&p=1&lang=EN&modeSearch=0&n=15
9 Oriental Digital Collection at the Royal Library in Copenhagen
http://www.kb.dk/en/nb/samling/os/osdigit.html
10 The Walters Museum, Baltimore Islamic Manuscripts Collection
http://art.thewalters.org/browse/category/islamic-manuscripts/
11 Cambridge Digital Library of Islamic Manuscripts
http://cudl.lib.cam.ac.uk/collections/islamic
12 Caro Minasian Collection of Arabic and Persian Manuscripts at the University of California, Los Angeles Library
http://digital.library.ucla.edu/minasian/
13 Digitized Manuscripts at the American University of Beirut Libraries
http://ddc.aub.edu.lb/projects/jafet/manuscripts/
14 Islamic Manuscripts at the University of Michigan, Ann Arbor
http://babel.hathitrust.org/cgi/mb?a=listis;c=1961411403 and http://www.lib.umich.edu/islamic/
15 ISMI: Islamic Scientific Manuscripts Initiative
http://echo.mpiwg-berlin.mpg.de/content/islam/islam
16 King Saud University
http://makhtota.ksu.edu.sa/MakhtotaEnglish.aspx
17 Library of Congress: Islamic Manuscripts from Mali
http://international.loc.gov/intldl/malihtml/
18 Markaz Wadud lil-Makhtutat
http://www.wadod.com/
19 Middle East Manuscripts at University of Pennsylvania Libraries
http://dla.library.upenn.edu/dla/medren/index.html
20 National Library of Bulgaria, Digital Library
http://www.nationallibrary.bg/cgi-bin/e-cms/vis/vis.pl?s=001&p=0192&n=&vis=
21 Oxford Digital Library: Features of the Bodleian Oriental Manuscript Collections
http://www2.odl.ox.ac.uk/gsdl/cgi-bin/library?site=localhost&a=p&p=about&c=orient02&ct=0&l=en&w=iso-8859-1
22 Turkish Ministry of Tourism and Culture Manuscripts Site
https://www.yazmalar.gov.tr/
23 University of Freiburg Oriental Manuscript Resource (OMAR)
http://omar.ub.uni-freiburg.de/index.php?id=omardatabank
24 Waqfiya al-Shaykh ‘Ali ibn ‘Abdallah al-Thani
http://www.sheikhali-waqfia.org.qa/SF/Ar/Manuscript/Default.aspx
25 Wellcome Library Arabic Manuscripts Online
http://wamcp.bibalex.org/home
26 Yale-SOAS Islamic Manuscript Gallery
http://www.library.yale.edu/ameel/
27 University of Birmingham, Mingana Virtual Collection
http://vmr.bham.ac.uk/Collections/Mingana/
28 U.S. National Library of Medicine - Turning the Pages Online
http://archive.nlm.nih.gov/proj/ttp/v2/books/#!/al_qazwini_wonders_of_creation/
29 Heidelberg University Library - Oriental Manuscripts Collection
http://www.ub.uni-heidelberg.de/helios/digi/codheidor.html
30 University of Tokyo Daiber Collection http://ricasdb.ioc.u-tokyo.ac.jp/daiber/db_index_eng.html
31 Mahaja Library Manuscript Collectionhttp://www.mahaja.com/library/manuscripts
32 The University Library in Bratislava, Ba agi ova Collection of Islamic Manuscripts
http://digitalna.kniznica.info/cgi-bin/library?site=localhost&a=p&p=about&c=basagic&l=sk&w=utf-8
33 An-Najah National University Libraries, Manuscript Collection
http://manuscripts.najah.edu/manuscripts
34 The Open Treasury for Islamic Manuscripts
http://totfim.com/fa/
35 Manuscript@CSIC portal
http://manuscripta.bibliotecas.csic.es/
36 IIUM Digital library http://www.lib.iium.edu.my/
37 Digital Library of Malay Manuscript
http://mymanuskrip.fsktm.um.edu.my
38 Digitized collections of the University Library Tübingen, Oriental Manuscripts
http://idb.ub.uni-tuebingen.de/digitue/tue/sammlungen/Ma_Orientalische_Handschriften/
39 Kiel University Library, Digitized Collections
http://www.ub.uni-kiel.de/digiport/uebersicht.html
40 University of Melbourne Library, Digital Repository Middle Eastern Manuscripts Collection
http://dtl.unimelb.edu.au/R/2IL1FCXQI9B1G6MYPPG2XTQ9X949VG79QTLTE8EKKKRKHSB2ES-02678?func=results-table
41 British Library Virtual Books, Baybars Quran
http://www.bl.uk/onlinegallery/virtualbooks/viewmostviewed/index.html
42 Word Digital Library http://www.wdl.org/en/item/31/
43 Iran Parliament Library Digital Collections
http://www.ical.ir/en/
44 Martin-Luther-Universität Halle-Wittenberg
http://menadoc.bibliothek.uni-halle.de/singledocs/nav/history?lang=en
45 Digital Library of the Islamic Republic of Iran
http://dl.nlai.ir
46 Virtual Library of the Mediterranean Sea (Manumed Project)
http://data.manumed.org/eng/treasures
47 Manuscriptorium
http://www.manuscriptorium.com
48 University of Utah, J. Willard Marriott Library Digital Collections
http://content.lib.utah.edu/cdm4/browse.php?CISOROOT=/uuappp
49 Brown University Library, The Minassioan Collection of Qur’anic Manuscripts
http://library.brown.edu/cds/projects/quran/browse-images/?page=11

OPEN ACCESS TO SCIENTIFIC RESULTS AND DATA. EUROPEAN UNION'S EFFORTS THROUGH OPENAIRE AND OPENAIREPLUS FP7 PROJECTS: CYPRIOT PARTICIPATION

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ABSTRACT:

The paper presents the introduction of Open Access movement in the Academic environment,pros and cons of the adoption of OA by Universities and how the European Union is enforcing the use of Open Access. The ways of implementing OA, the policies of publishers and journals regarding the deposits of publications and the RoMEO and Juliet projects are also referred in an effort to give an overview of the conditions in exploiting Open Access, either as authors, publishers or end users. The adoption of the Berlin declaration on Open Access to Knowledge in the Sciences and Humanities by the Senate of the University of Cyprus is commented in the paper. Furthermore an analysis of the projects OpenAIRE and OpenAIREplus in which the University of Cyprus Library is involved is provided.

1. OPEN ACCESS

1.1 The way to Open Access – a short overview

The pricing of journals over the last few decades has been leading to a decline in the availability of academic research results. Academia reached the level where even the affluent research institutions cannot afford access to the full range of research literature (Suber). Enforcing this statement we can see the recent movement of the Harvard Faculty Advisory Council to the Library, representing university faculty in all schools and in consultation with the Harvard Library leadership on the 17th of April 2012, reaching the following conclusion: "major periodical subscriptions, especially to electronic journals published by historically key providers, cannot be sustained: continuing these subscriptions on their current footing is financially untenable. Doing so would seriously erode collection efforts in many other areas, already compromised". The announcement closes with the encouragement to the faculty and students (F) and the Library (L) as follows:

- Make sure that all of your own papers are accessible by submitting them to DASH in accordance with the faculty-initiated open-access policies (F).

- Consider submitting articles to open-access journals, or to ones that have reasonable, sustainable subscription costs; move prestige to open access (F).

- If on the editorial board of a journal involved, determine if it can be published as open access material, or independently from publishers that practice pricing described above. If not, consider resigning (F).

- Contact professional organizations to raise these issues (F).

- Encourage professional associations to take control of scholarly literature in their field or shift the management of their e-journals to library-friendly organizations (F).

- Encourage colleagues to consider and to discuss these or other options (F).

- Sign contracts that unbundle subscriptions and concentrate on higher-use journals (L).

- Move journals to a sustainable pay per use system, (L).

- Insist on subscription contracts in which the terms can be made public (L).

This is a movement we can see been followed by many institutions that cannot afford or just disagree with the policies and prices of the journal providers.

1.2. Defining Open Access

European Commission defines "Open access", as free access over the internet, which aims to improve and promote the dissemination of knowledge, thereby improving the efficiency of scientific discovery and maximising return on investment in R&D by public research funding bodies**.

Peter Suber defines open access as the digital, online, free of charge, and free of most copyright and licensing restrictions method of having access to scientific topics. What makes it possible is the internet and the consent of the author or copyright-holder (Suber).

OA was physically and economically impossible in the age of print, even if the copyright holder wanted it. Prices were not only unavoidable for print journals; they were even affordable until the 1970's, when they began to rise faster than inflation.

** European commission – European research area open access pilot in FP7 http://ec.europa.eu/research/science-society/open_access

Journal subscription prices have risen nearly four times faster than inflation since 1986 (Kyrillidou, 2004).

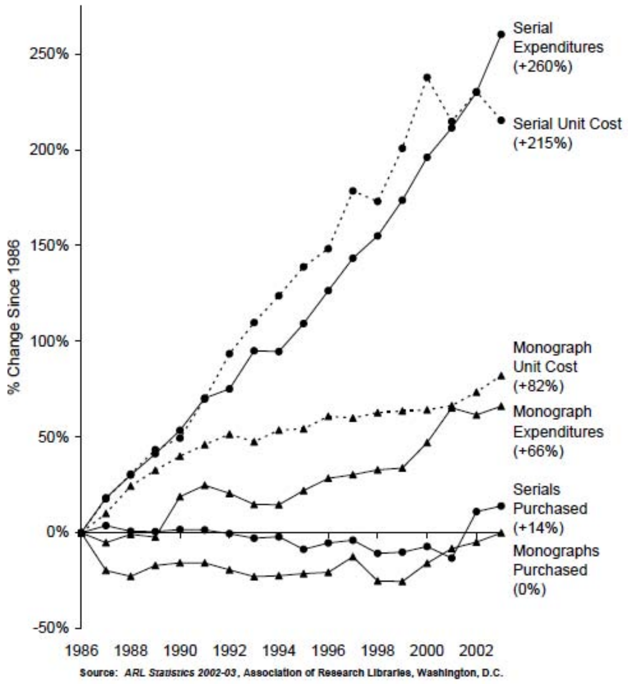

Figure 1. Monograph and serial costs in ARL Libraries, 1986 - 2003 (Kyrillidou, 2004)

Fortuitously, just as journal prices were becoming unbearable, the internet emerged to offer an alternative (Suber). This alternative was named Open access

1.3. Publisher and journal policies

Open access can be provided in two ways:

The **Green route** where the author can self-archive at the time of submission of the publication, whether the publication is grey literature (usually internal non-peer-reviewed), a peer-reviewed journal publication, a peer-reviewed conference proceedings paper or a monograph and **the Gold route** where the author or author institution can pay a fee to the publisher at publication time and the publisher thereafter will make the material available 'free' at the point of access.

The two are not, of course, incompatible and can co-exist (Jeffery, 2006).

Publishers provide specific policies regarding how authors can deposit their own publications. These policies are concentrated and can be found in RoMEO[†] (a searchable database of publisher's policies regarding the self- archiving of journal articles on the web and in Open Access repositories).

Researchers or academic community can use RoMEO to find out whether the publishers' copyright rules allow them to deposit in their institutional repository. It summarizes publishers' conditions and categorizes publishers by colours, indicating level of author rights. Finaly RoMEO shows which publishers' comply with funding agencies' conditions.

As a way to complement RoMEO service SHERPA provides JULIET which lists summaries of publishers' copyright transfer agreements as they relate to archiving. Further information on Open Access is available for authors, including links to contacts and repositories which may be able to take eprints to fulfill funders' requirements and recommendations.

1.4. European Union's view

In the mid of the previous decade the European Commission funded a "Study on the economic and technical evolution of the scientific publication markets in Europe" in order to define the situation and formulate an appropriate strategy (Dewatripont 2006). One of the European Union's visions is the one stated by the Commissioner for Research, Innovation and Science, Máire Geoghegan-Quinn: "We need a European Research Area that is interconnected, structured, mobile and efficient; a unified research area that brings together people and ideas in a way that catalyses science and world-leading innovation. Open access can help make this vision become a reality".

In August 2008, the European Commission launched the 'Open Access Pilot in the Seventh Framework Programme (FP7), intended to provide researchers and other interested members of the public with improved online access to EU-funded research results.

The pilot aims to permit easy and free access to scientific information, in particular peer-reviewed scientific articles published in journals. Articles covered by the pilot will become accessible after an embargo period of 6 or 12 months, depending on the FP7 area.

The difference in embargo periods in Open Access (6 months or 12 months) is explained by the fact that research findings are considered 'new', and therefore have an economic value for different periods of time depending on the scientific discipline. The length of time after which the research results of rapidly changing disciplines (e.g. ICT) become out of date is relatively shorter than in the case of, for example, research results in the social sciences, which remain valid for a longer period. This model is in keeping with approaches developed by other funding bodies (the Commission's pilot is only one of many initiatives underway in Europe and beyond, such as WELCOME Trust).

1.4.1. EU funded projects

EU has several funded projects for implementing and/or supporting Open Access, such as:

ACUMEN (Academic Careers Understood through Measurement and Norms)
APARSEN (Metadata for preservation, curation and interoperability)
BELIEF II (To Promote the Efficient and Effective Communication of Results, Networking and Knowledge among EU e-Infrastructure Projects and their Users)
CESSDA (Council of European Social Science Data Archives)
CLARIN (Common language resources and technology infrastructure)
COMMUNIA (Thematic Network on the Public Domain in the Digital Environment)
DARIAH (Digital Research Infrastructure for the Arts & Humanities)
DRIVER II (Digital Repository Infrastructure Vision for European Research)

***The RoMEO Project (Rights MEtadata for Open archiving) was funded by the Joint Information Systems Committee for one year (1 August 2002 - 31 July 2003) to investigate the rights issues surrounding the 'self-archiving' of research in the UK academic community under the Open Archive Initiative's Protocol for Metadata Harvesting.

e-SciDR (Towards a European Infrastructure for e-Science Digital Repositories)
EUROCANCERCOMS (Establishing an Efficient Network for Cancer Communication in Europe)
EUROVO-AIDA (Euro-VO Astronomical Infrastructure for Data Access)
LiquidPub (Liquid Publications: Scientific Publications meet the Web – Changing the Way Scientific Knowledge is Produced, Disseminated, Evaluated, and Consumed)
MEDOANET (Mediterranean Open Access Network)
NECOBELAC (Network of Collaboration between Europe and Latin American-Caribbean Countries)
OAPEN (Open Access Publishing in European Networks)
ODE (Opportunities for Data Exchange)
OpenAIRE (Open Access Infrastructure for Research in Europe)
OpenAIREplus (2nd Generation of Open Access Infrastructure for Research in Europe)
PARSE.Insight (Permanent Access to the Records of Science in Europe)
PEER (Pilot Programme Investigating the Effect of the Deposit of Author Manuscripts on the Ecology of European Research and Publishing)
SISOB (An Observatorium for Science in Society based in Social Models)
SOAP (Study of Open Access Publishing by Key Stakeholders)

1.5. University of Cyprus actions

The Senate of the University of Cyprus, during its 23rd meeting of 2008 which took place on the 5th of November of 2008, supported and accepted the Library Committee's proposal to sign the Berlin Declaration.

The Senate as the highest academic body of the University of Cyprus and responsible for the academic affairs of the University, decided to share the vision expressed in the Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities.

The name of the University of Cyprus is included in the signatories list of the Berlin Declaration:

http://oa.mpg.de/lang/en-uk/berlin-prozess/signatoren/.

Furthermore the Library of the University of Cyprus is involved in two European Research projects (OpenAIRE and OpenAIREplus). Both projects aim the support of the implementation of Open Access in Europe.

2. OPENAIRE‡

2.1. OpenAIRE overview

OpenAIRE, a three-year project funded by the 7th Framework Programme, aims to support the implementation of Open Access in Europe. OpenAIRE is establishing the infrastructure for researchers to support them in complying with the European Commission (EC) OA pilot and the European Research Council (ERC) Guidelines on Open Access. It provides the means to promote and realize the widespread adoption of the Open Access Policy, as set out by the ERC and the by the European Commission. It provides an extensive European Helpdesk System, based on a distributed network of national and regional liaison offices in 27 countries, to ensure localized help to researchers within their own context. It has built an OpenAIRE portal and e-Infrastructure for the repository networks and is exploring scientific data management services together with 5 disciplinary communities. It provides a repository facility for researchers who do not have access to an institutional or discipline-specific repository. As Neelie Kroes, Vice-President of the European Commission for the Digital Agenda said: "The launch of OpenAIRE marks a very concrete step towards sharing the results of EU funded research to our mutual benefit. Scientific information has the power to transform our lives for the better – it is too valuable to be locked away. In addition, every EU citizen has the right to access and benefit from knowledge produced using public funds".

2.1.1. OpenAIRE's objectives

OpenAIRE's three main objectives are to:

- build support structures for researchers in depositing FP7 research publications through the establishment of the European Helpdesk and the outreach to all European member states through the operation and collaboration of **27 National Open Access Liaison Offices**;
- establish and operate an electronic infrastructure for handling peer-reviewed articles as well as other important forms of publications (pre-prints or conference publications). This is achieved through a portal that is the **gateway** to all user-level services offered by the e-Infrastructure established, including access (search and browse) to scientific publications and other value-added functionality (post authoring tools, monitoring tools through analysis of document and usage statistics);
- work with several subject communities to explore the requirements, practices, incentives, workflows, data models, and technologies to deposit, access, and otherwise **manipulate research datasets** of various forms in combination with research publications.

Currently the European Commission has two policies on Open Access in practice. Both aim to ensure that research results funded by the EU citizen are made available to the population at large for free. In this way, Open Access is considered a way to improve the EU's return on research and development (R&D) investment.

In December 2007, the ERC Scientific Council published its Guidelines for Open Access, as a follow up of the 2006 Statement on Open Access. In August 2008, the European Commission launched the Open Access Pilot in FP7 that will run until the end of the Framework Programme.

These initiatives require that the researcher **provides open access to articles resulting from EC funded research, within a specified time period**. Both initiatives have further special requirements; see ERC Guidelines for Open Access and Open Access Pilot in FP7.

ERC or from FP7 in one of the following Research Areas:

Energy, Environment (including Climate Change), Health, Information and Communication Technologies (Cognitive Systems, Interaction, Robotics), Research Infrastructures (e-infrastructures), Science in society and Socio-economic sciences and the humanities.

Grant agreements in these areas signed after the beginning of the open access pilot will contain a special clause (39) requiring beneficiaries:

1. to deposit articles resulting from FP7 projects into an institutional or subject based repository;

2. to make their best efforts to ensure open access to these articles within six months (Energy, Environment, Health, Information and Communication Technologies, Research

‡ All the information for OpenAIRE was taken from the official OpenAIRE project website (www.openaire.eu).

Infrastructures) or twelve months (Science in Society, Socio-economic Sciences and Humanities).

Researchers should deposit final articles or manuscripts into the institutional repository of the research institution with which they are affiliated. If this is not possible, they should identify an appropriate subject based/thematic repository. The Commission provides a special repository for articles that can be stored neither in institutional nor in subject-based/thematic repositories.

Researchers should deposit final articles or manuscripts into:

- institutional repository of the research institution with which they are affiliated
- appropriate subject based/thematic repository.
- the **Orphan Repository**[§] for articles that can be stored neither in institutional nor in subject-based/thematic repositories.

OpenAIRE's Orphan Repository is hosted by CERN and every researcher is free to deposit his/her publication in it.

2.1.2. University of Cyprus Library role

The University of Cyprus Library participates in the project as a National Open Access Desk (NOAD). The NOADs **connect** researchers, research institutions, and policy makers at a national level on the one end, and the OpenAIRE project services on the other. The focus of the National Open Access Desks activities is on **support** for compliance with the EC Open Access Pilot.

The National Open Access Desk can help researchers to **find the appropriate repository** in their native country, and can **answer their questions** concerning Open Access, the EC Open Access Pilot, copyright issues, any special national rules and regulations concerning Open Access, and so on. In principle each NOAD can provide the necessary information with respect to OpenAIRE, Open Access in general and the EC Open Access Pilot. They will redirect questions if necessary, especially when national issues, like copyright, are involved.

The University of Cyprus Library as the regional NOAD of Cyprus offers LEKYTHOS (academic – institutional repository of the University of Cyprus) to all the local researchers that would like to deposit their publications derived from projects funded under the scientific Areas above. **Institutional Repositories** are repositories that are maintained and curated by institutions - very often the library. Repositories collect, curate and make the research output of an institution available on the Internet. LEKYTHOS is fully compatible with the OpenAIRE platform and all the publications deposited in LEKYTHOS will become visible through the OpenAIRE platform also. Cyprus NOAD provides support to all the regional repository managers in Cyprus in order to help them in their effort to comply with the OpenAIRE platform.

2.2. OpenAIREplus[**]

OpenAIREplus (2nd Generation of Open Access Infrastructure for Research in Europe) was launched in Pisa in early December. The 30 month project, funded by the EC 7th Framework Programme, will work in tandem with OpenAIRE, extending the mission further to facilitate access to the entire Open Access scientific production of the European Research Area, providing cross-links from publications to data and funding schemes. This large-scale project brings together 41 pan-European partners, including three cross-disciplinary research communities.

The project will capitalise on the successful efforts of the OpenAIRE project which is rapidly moving from implementing the EU Open Access Pilot project into a service phase, enabling researchers to deposit their FP7 and European Research Area (ERA) funded research publications into Open Access repositories. The current publication repository networks will be expanded to attract data providers from domain specific scientific areas. "The participatory design of OpenAIREplus will seamlessly guide the researcher to Open Access research data. The experienced consortium will pave the way to support the research work of European scientists and open up the road to multi-disciplinary science" says Dr. Norbert Lossau, Scientific Coordinator of OpenAIREplus and Director of Göttingen State and University Library, Germany.

Creating a robust, participatory service for the cross-linking of peer-reviewed scientific publications and associated datasets is the principal goal of OpenAIREplus. As scholarly communication touches upon many disciplines, the project's horizontal outreach will facilitate collaboration across data infrastructures, providing information to scientists, non-scientists as well as to providers of value-added services. The project will establish an e-Infrastructure to harvest, enrich and store the metadata of Open Access scientific datasets. Innovative underlying technical structures will be deployed to support the management of and inter-linking between associated scientific data.

Access to and deposit of linked publications via the OpenAIRE portal will be supported by a Help Desk, and OpenAIRE's collaborative networking structure will be extended to promote the concept of open enhanced publications among user communities. Liaison offices in each of the project's 31 European countries work to support the needs of researchers in Europe. The project will also actively leverage its international connections to contribute to common standards, data issues and interoperability on a global level. The University of Cyprus Library participates in OpenAIREplus by representing the Cypriot NOAD in the same way as in OpenAIRE.

OpenAIREplus uses the publication base, the software tools & services, the studies' results, and the extensive pan-European network of national representatives of the DRIVER and OpenAIRE infrastructure as a starting point. It enhances and expands the current functionality, interfaces, helpdesk services, and other activities to become operational in and consistent with the new environment envisioned.

Furthermore, it pushes on the following new main issues:

1. It expands the scope of the OpenAIRE technical and human infrastructure beyond the restricted realm of publications from project funded by the EC and having to abide to Special Clause.39, effectively offering an Open Access infrastructure to the entire scientific production of the European Research Area. Such an infrastructure does not exist at the moment but is crucial to foster growth and innovation.

2. In addition to dealing with publications, it also opens up to scientific datasets to a certain degree but in the same generic fashion. It harvests corresponding metadata from relevant repositories, aggregates them appropriately, and serves them to the other infrastructure services, e.g., search facilities and user functionality, similarly to publication metadata. It also offers a repository where researchers can deposit "homeless" datasets pertaining to their publications, if no other suitable repository

[§] The term "orphan" was replaced with the term "homeless" for this category of publications within the OpenAIRE consortium.

[**] All the information for OpenAIREplus was taken from the official OpenAIRE project website (www.openaire.eu)

exists. Central to this effort are services for cleaning and curation of the harvested metadata.

3. It offers services for several kinds of enrichment of the harvested metadata. Of key importance is the automatic, semi-automatic, or manual identification of links between publications and related datasets, projects, or other publications, and subsequent OpenAIREplus presentation of the resulting composite objects (rich enhanced publications) through appropriate visual representations. The starting point for this is the preliminary enhanced publication model (between publications only) prototyped in DRIVER-II. Equally significant are the extraction and derivation of other critical information, such as subject identification, bibliographic and usage trends detection, and other statistics calculations. Central to this effort are services for mining the harvested metadata and possibly other resources at various levels and for visualization of restricted data forms.

4. It makes its scientific information resources available to higher-level applications and providers of value-added services as well as to new communities and sections of society, e.g., scientists from disciplines other than those producing the resources, industry, or even the general public. It offers multiple interaction pathways to its content, each one appropriate for the characteristics of a different consuming application type or the interests and backgrounds of a different user type. Furthermore, it develops functionality enabling active participation of scientists and its general user constituency in the formation, enrichment, and use of the infrastructure content. Central to this effort are services related to adaptation and customization, community formation and interaction, and user interfaces.

5. It establishes connections with other infrastructures and several diverse forms of research content systems (e.g., D4Science, UKPubMed, DANS, other repositories, data archives, CRISs, DataCite) to enable harvesting of their resources. Given the present heterogeneity of such systems in terms of software platforms, service interfaces, and content formats, OpenAIREplus puts particular emphasis on establishing interoperability among them and its infrastructure. Central to this effort are the use of standards and services for harmonizing the differences among participating systems.

6. It studies several thorny issues related to the legal status of publications and datasets and promotes particular open-access licensing models for specific contents, so that the desired open access to all resources by several communities can be realized. Central to this effort are issues related to provenance, intellectual property rights, and conditions of reuse.

7. Likewise, it studies and analyses several possible models and options for a possible longterm scenario and an according business model that aims at the sustainability of the infrastructure.

3. OPEN ACCESS AND CULTURAL HERITAGE

3.1. Europeana : the portal to cultural heritage

Europeana is an internet portal that acts as an interface to millions of books, paintings, films, museum objects and archival records that have been digitised throughout Europe.

Among professionals in the heritage sector, Europeana is also a platform for knowledge exchange that promotes collaboration between librarians, curators, archivists and the creative industries.

Europeana gives access to different types of content from different types of heritage institutions, such as libraries, museums, archives etc. The digital objects can be found and accessed by users online via the networks of the cultural institution that owns it and hosts it. Europeana collects **contextual information – or metadata** – about the items, including a small picture. Users search this contextual information. Once the users find what they are looking for, if they want to access the full content of the item, they can click through to the original site that holds the content.

Cyprus is involved in this project by contributing digital objects of the local cultural heritage. A local aggregator which concentrates the digital objects is created and heritage institutions in cooperation with the local Ministry of Education and Culture, are providing important historical cultural heritage objects to the public through Europeana.

In order for the content to be provided via the portal, the institutions have to sign the "Data exchange agreement[1]", which among others, assures that the objects can be freely available and the data provider has made best efforts to provide Europeana with correct Metadata on the Intellectual Property Rights to the Content, including the identification of Content that is Public Domain as being Public Domain (Article 2, paragraph 3.).

The University of Cyprus library has signed the "Data exchange agreement" in April 2012, and has already provided around 4000 cultural heritage objects.

The content of Europeana falls in the grey zone of the definition of an object as a cultural heritage document and a pure raw research data. For example, providing an audio object with an interview of a veteran warrior telling his story and point of view, might have historical importance but it might also have importance for the research of a political analyst or an interest for a linguistic researcher.

Open access to any kind of cultural heritage documents, is giving the chance to users/researchers to have access in important items, where they can find valuable sources for their research.

In addition a country can benefit in several socioeconomic ways by showing the culture and the civilization of the country, the origins the habits of people living there etc

Concluding is important to mention that Open access for a small country like Cyprus has a bigger marginal value than other countries of the E.U. Taking part in projects like Europeana or any other projects supporting Open access can only benefit Cyprus.

3.2. Public Sector Information (PSI) and Orphan works directives

The Council and the European Parliament have adopted The Directive on the re-use of public sector information which deals with the way public sector bodies should enhance re-use of their information resources (the Directive 2003/98/EC of 17 November 2003 was published in the Official Journal (L345/90) on 31 December 2003).

The Directive is built around two key pillars of the internal market: transparency and fair competition. It sets minimum rules for the re-use of PSI throughout the European Union. In its recitals it encourages Member States to go beyond these

[1] The Data exchange agreement is available online through the address: http://pro.europeana.eu/documents/10602/560317/Data+Exchange+Agreement+-+Final+-+clean.pdf

minimum rules and to adopt open data policies, allowing a broad use of documents held by public sector bodies.

In parallel there is the Orphan works directive. The Commission has adopted a Proposal for a Directive on certain permitted uses of orphan works with a view to establishing common rules on the digitisation and online display of so-called orphan works. Orphan works are works like books, newspaper and magazine articles, and films that are still protected by copyright but whose authors are not known or cannot be located or contacted to obtain copyright permissions. Orphan works are part of the collections held by European libraries that might remain untouched if no common rules are developed to make their digitisation and online display legally possible. Common rules on how to deal with such works are therefore necessary in order to proceed with large-scale digitisation projects, such as the Commission's *Europeana* portal.

Both directives are working as reinforcements made by the European Commission for introducing Open Access in EU member states .

4. CONCLUSION

According to the OpenAIRE project (www.openaire.eu) there are significant economic, social and educational benefits to making research outputs available without financial, legal and technical barriers to access. Open Access to conclude incorporates national research into an interoperable network of global knowledge, increases national research impact, provides new research partnerships, and removes professional isolation.

Society as a whole benefits because research is more efficient and more effective, delivering better and faster outcomes for all. Open Access strengthens economies through developing a strong and independent national science base. There is growing evidence that countries also benefit because Open Access increases the impact of the research in which they invest public money and therefore there is a better return on investment (Houghton, 2009). This new approach is leading today's publishing attitude and the University of Cyprus Library will continue to support and comply with all the EU recommendations regarding the Open Access publishing.

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THE MUSEUM ENVIRONMENT: A COMPLEX COMMUNITY OF OBJECTS, PEOPLE AND DEVICES

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KEY WORDS: Interactive exhibits, Mobile technologies, Interactive displays, Museum visitors, Visitor engagement, Interaction framework

ABSTRACT:

The beginning of the 21st century is an exciting time for museums in terms of new, engaging and interactive exhibits. Current technological developments offer museums ideal opportunities to meet the increasing expectations of their visitors, many of whom are the younger generation growing up in the digital age. With a multitude of devices and objects as well as people incorporated into an ever-growing network of interconnected systems, new patterns, forms of interactions and social relations will emerge. In order to engage visitors, museums are adopting new technologies which come with many possibilities, but also have their individual challenges and limitations. Museums should start looking at the unification of many such technologies in order to capture visitor attention, engage visitor interaction and facilitate social activities, since the large quantity of digital input and output capabilities of these technologies are hidden potentials. However, unless specifically designed for, many of these capabilities remain hidden and technologies remain oblivious of each other's features. Making them aware of each other's capabilities opens the channels for new synergy and engaging experiences for museum visitors. This paper proposes a framework which uniquely identifies a community of people, artefacts and devices within the museum environment and provides the means to discover, and make use of the technological properties of each element, treating them as an interacting ecosystem of complex adaptive systems and networks in physical spaces.

1. INTRODUCTION

For most people a museum visit is often a social event and they expect their visit to be fun, social and educational, with interactive and engaging exhibits (Black, 2005). In order to meet these expectations museums are adopting new technologies and creatively applying that which they have adopted so that visitors are engaged in a more personal and social experience. One of the greatest challenges for museums is to make the technology unobtrusive for their visitors and also to keep a low 'technological footprint'. Well designed Smartphones are perhaps the first technology to meet these two expectations: they get carried in by visitors, and they are taken away when they leave, and are personal items with which visitors are familiar – they know how to use it. Multi-touch, multi-user tables are another promising technology. These surfaces come with large touch-screen displays with great computing power. Nevertheless, the mode of gestural interactions is similar to Smartphone interaction styles. The existence of multi-touch, multi-user tables within a museum presents a familiar home-like environment. They appeal to aspects of users' daily lives around dining and study tables, such as using horizontal surfaces as a workspace and using gestures to manipulate and interact with information (Geller, 2006).

In the Internet of Things (Atzori *et al.*, 2010), everyday objects become part of an ever-growing network of interconnected systems, inhabiting the world we lived in as unique, substantive actants. Besides, "objects are a cause, a medium, and a consequence of social relationships" (Riggins, 1994). Museums with a multitude of artefacts, people and devices are interconnected systems and open channels that affect museum visitors. They provide them with new and engaging experiences, which they may not have seen before. Eventually, technology could become ubiquitous, a part of our expectations of interactive exhibits and the museum environment (Parry *et al.*, 2005).

People, objects and devices within museums can be part of a complex society, interwoven in complex relationships. From this network, patterns of interactions and social relationships are expected to emerge. These patterns may be predictable or they may not have any order. Networks of interconnected entities which interact based on simple rules may give rise to complexity; they frequently demonstrate interesting phenomena (Miller *et al.*, 2007). The adaptation, flow and communication of information within a network of interconnected systems may collectively produce emergent (Holland, 1998) and self-organising behaviour (Halley *et al.*, 2008) which may reveal interesting patterns in the collective behaviour of museum visitors from which we could take advantage of for managing and guiding visitors, therefore providing them with better experiences during the visit. The aim of this paper is to provide a framework for facilitating the information flow and communication within a community of interactive people, devices and artefacts. The foundation laid in this paper will eventually lead to a wealth of data within which concepts in complexity theory may be used for studying the patterns, and leverage the patterns for managing museum experiences.

Section two provides the background information on the museum environment, how it can be transformed by the Internet of Things. This will lay a foundation for the framework based on previous studies and research. Section three describes the framework, called Sytizen. This is followed by discussions and conclusion. The paper closes with suggestions for future work.

2. A COMPLEX ENVIRONMENT

With a wide variety of exhibits, a multitude of artefacts and visitors bringing their own mobile devices, the museum environment becomes a large network of interconnected entities (see Figure 1). These elements have common characteristics and once mirrored into a digital environment, they can generate, manipulate, and exchange information. A visitor who wishes to interact with an exhibit, the museum that guides visitors along its collections, or an artefact conveying historical meanings; they all become part of one large community of information exchange.

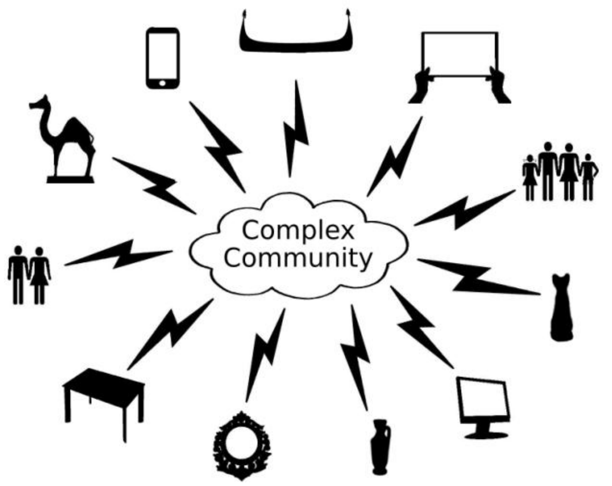

Figure 1: A complex community within the museum environment with artefacts, people and devices.

2.1 Transforming the Museum Environmet

Visitors come to museums in pairs or groups. What they learn from their visits and the knowledge they take home is often the outcome of discussions and the sharing of each other's experiences. Museums should therefore encourage social interaction; they are responsible for providing a well managed environment where visitor needs are satisfied (Black, 2005).

As there is a limit as to how long visitors can spend time within a museum, they like to fill their leisure time with new experiences, worthwhile activities, something they can learn from. Whether this originates from their curiosity for the past, the present or the future, museum visitors satisfy their desire to learn, discover and understand (Herbert *et al.*, 1989). They want to participate actively, be part of the experience and engage not only with the collections, but also with each other (Hood, 1996). This has led to the development of interactive exhibits which appeals to both families and the younger generations alike.

Museums have been creating interactive exhibits not only by adopting new technologies, but also by reusing existing ones, recreating interactive installations and providing hands-on experiences for their visitors. Exhibits where visitors are actively involved and have a hands-on experience are found to be very attractive (Hornecker *et al.*, 2006). They are considered to be more enjoyable and worth revisiting compared to traditional exhibits (Michael *et al.*, 2010). These exhibits can even extend the time visitors interact with them (Witcomb, 2006). However, supporting only single user interaction introduces a trade-off between user immersion and social activity (Hornecker, 2010). As visitors often co-explore the interactive exhibits and created private experiences within the public environment (vom Lehn *et al.*, 2007), it emphasises the need for museums to not only focus on contents for individuals but also on the museum environment to encourage social interaction.

At present, mobile technologies have subtly pervaded society and have transformed it in unexpected ways. Smartphones could become the gateway to interact with ubiquitous computing applications. They offer a whole range of input and output capabilities which can be used to enhance the visitor experience and interaction, for example in combination with an interactive display the limited visual output capabilities of mobile devices could be overcome (Forman *et al.*, 1994). Additionally they allow for both access control and personal storage (Hardy *et al.*, 2008) and could also give users a greater sense of privacy. However, setting up data connections between mobile devices and other technologies should be made easy, fast and reliable (Ballagas *et al.*, 2006). Technological developments such as the Quick Response (QR) Codes and wireless non-contact systems such as Radio-Frequency Identification (RFID) and Near Field Communication (NFC) make this a viable reality. In the Internet of Things, artefacts, exhibits and the museum environment become part of a network of interconnected entities, thereby gaining their own identity in the physical as well as the virtual environment. While the technology remains unobtrusive, this allows localised user interaction to provide user specific content (Pering *et al.*, 2005). Additionally, since visitors can use their own Smartphones to interact with this vast network, the 'technological footprint' is essentially non-existent. Some museums already make clever use of these technologies by fitting their artefacts and exhibits with these technologies, making them part of larger interconnected systems (e.g. Blöckner *et al.*, 2009; Cosley *et al.*, 2009; Hsi *et al.*, 2005; Simatic *et al.*, 2009).

Fleck *et al.* (Fleck *et al.*, 2002) developed a nomadic computing system for a museum with many 'hands-on' exhibits. Their goal was to provide visitors additional information depending on their location within the museum. For this they made use of mobile devices and RFID tags. However, since the museum offered many 'hands-on' experiences, the mobile devices restricted the visitors to interact with the exhibits themselves. An important lesson for future development is that when the goal is to enhance existing visitor experiences, mobile devices should not restrict the visitor. Instead, they could be made part of the 'hands-on' experience by making them part of the interaction. Blöckner *et al.* (Blöckner *et al.*, 2009) addressed this by transforming mobile devices into interfaces through which visitors could interact with an interactive display, explore the museum environment and download content on their mobile devices.

Kuflik *et al.* (Kuflik *et al.*, 2007) aimed to enhance the social interaction within groups of visitors. They developed a context-aware communication service which supported user-user and system-user communication. Visitors could inform each other of interesting artefacts and exhibits or leave post-its for other visitors. The system that Kuflik *et al.* developed can also provide additional information about an exhibit and inform visitors to view highly recommended exhibits as a priority when time is a limitation. During a user study Kuflik *et al.* (Kuflik *et al.*, 2011) found that although visitors liked the user-user communication and thought it was useful, they were less motivated to actively get additional information available at the system. According to Kuflik *et al.* visitors prefer information push over information pull; they are interested in information that is presented to them (e.g. a label next to an artefact) but are less motivated to actively retrieve additional information themselves (e.g. by scanning QR Codes). More importantly, Kuflik *et al.* noted that engaging the visitor is one of the most challenging aspects, and that combinations of technologies will be the next step in order to create both engaging and social visitor experiences.

2.2 One Big Community

Besides mobile technologies, museums have been adopting other technologies such as portable game consoles, motion sensing input devices, interactive displays and even complete electro-mechanical machines in order to engage their visitors. The large quantity of digital input and output capabilities of these technologies are, however, hidden potentials. Museums should therefore start looking at the unification of many of these technologies in order to capture visitor attention, engage visitor interaction and facilitate social activities.

However, unless specifically designed for, as in the work of Fleck *et al.* (Fleck *et al.*, 2002) or Kuflik *et al.* (Kuflik *et al.*, 2007), these technologies have little knowledge of each other. Once visitors, devices and artefacts are engulfed in the museum environment and becoming part of a big community, this allows them to explore each other's capabilities, opening channels for new synergy and engaging experiences. From this community, patterns of interactions and social relationships are expected to emerge. These patterns may be predictable or they may not have any order. Approaching this bottom-up, defining the individual elements first and then provide the means to link them together, allows to give rise to new interaction methods and interactive systems.

3. SYTIZEN

The framework proposed in this paper is called Sytizen, a combination of the word ci**tizen**, as being part of a community, and the Greek word **sy**nergia, meaning "working together". Sytizen allows the identification of a community of people, artefacts and devices within the museum environment and provides the means to discover, and make use of the technological properties of each element. These two aspects of the framework are separated into Identification and Specification respectively and are described below.

3.1 Identification

In order to identify individual elements within the museum environment (e.g. artefacts, exhibits, visitors), without categorizing them other than on common characteristics of generating, manipulating and exchanging information, the entire environment is regarded as a single group, the Community. Within the Community individual elements, Citizens, are defined by a Passport and a Location (see Figure 2). The Passport and can be utilized to identify a unique Citizen and consists of a UUID, a randomly generated 128-bit value. This enables a decentralised system in order to facilitate a dynamically changing environment. Every Citizen can also be fitted with a Location, containing an IP address (either IPV4 or IPV6) and a port number to support connectivity between individual elements.

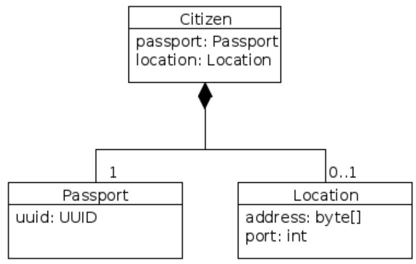

Figure 2: Definition of a Citizen, containing a Passport and a Location which is optional.

The amount of data needed to describe a Citizen is relatively small and can therefore easily be stored on an NFC/RFID tag or even in QR codes. Citizens can represent any element within the museum environment and once it acquires the description of another Citizen (e.g. by scanning a NFC tag) a connection can be established. Once connected, they can begin to exchange specifications and make use of each other's technological properties.

3.2 Specification

To get insight in the input and output capabilities of a Citizen, the framework allows connected Citizens to discover and explore each other's specifications. A Citizen's specification is composed of a System description, which represents the entire set of its capabilities described as Interfaces and EndPoints (see Figure 3). The fundamental parts of a System description are its EndPoints. They provide the actual link to an input or output (e.g. GPS position, orientation, data storage).

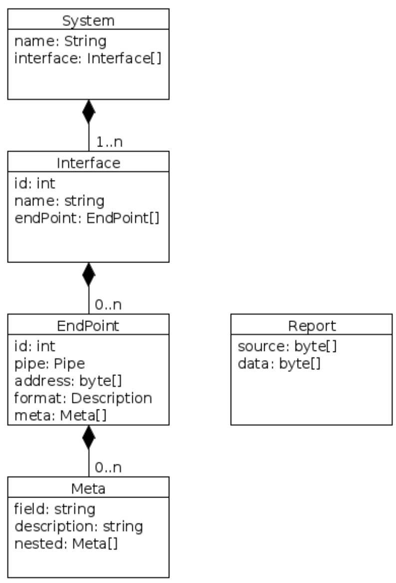

Figure 3: Definition of a System specification. For development purpose EndPoints can be fitted with Meta-data, describing its format in a human-readable form.

Interfaces can contain groups of EndPoints which describe an analogous input or output. For example, Citizen's location information can be based on GPS, IP address or even on available wireless network. EndPoints describing a Citizen's location can therefore be bundled into a single Interface.

In order to describe the direction of the data flow, EndPoints can be defined as an input or output. Additionally, they can also be defined as a Control EndPoint, indicating they can be used to active or deactivate the Interface or change some of its settings (e.g. data sampling rate). Two other important aspects of an EndPoint are its format and address. To make sense of the input or output data, an EndPoint's format contains a description of the data it will send, or wants to receive. In order to exchange data, EndPoints rely on Reports which contain a reference to the EndPoint's address, and the actual data as described in the EndPoint's format. This information is all another Citizen needs to reconstruct the original data and make use of it.

3.3 Protocol

Both Identification and Specification descriptions, as well as the Reports containing the actual data should be communicated according to a structured method. The final aspect of Sytizen defines its protocol – a set of rules and procedures which have to be followed when communicating.

The protocol is separated into three layers, Identification, Specification and Communication. Each individual layer handles a part of the interaction between two Citizens (see Figure 4).

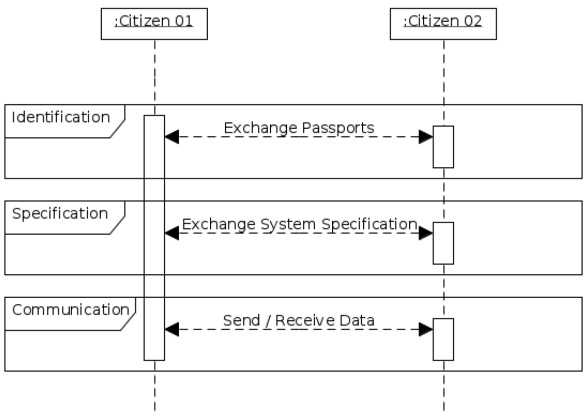

Figure 4: The three layers of the framework's protocol, Identification, Specification and Communication. Each layer handles its own part in order to identify other elements, provide the means to discover or make use of the technological properties.

Once two Citizens are connected, the first step is to introduce each other by exchanging Passports. This happens in the Identification layer and allows Citizen to validate each other and could, for example, be used for access control or profile management. Additionally this also provides the means to distinguish between different Citizens when more than one connected. The second step takes place in the Specification layer. If a Citizen is interested in the technological capabilities of the other party, it can request its System specification. It will then be able to explore the input and output capabilities of the other party and decide whether, and which feature to utilize. The actual data will be sent in the third and last layer, Communication.

Messages for each layer are wrapped in a generic format (see Figure 5) which allows the framework to be easily extended in the future without losing its current capabilities.

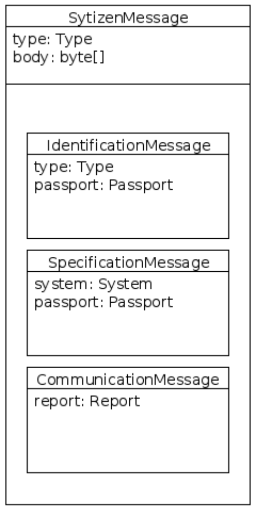

Figure 5: Definition of the framework's generic format. Each Identification, Specification or Communication message is encapsulate in a SitizenMessage.

3.4 Proof of Concept

To demonstrate the strengths of Sytizen, an experimental prototype was developed, representing an interactive exhibit.

The prototype includes a simple LCD display and a Smartphone. The display is fitted with an NFC tag which can be scanned by the Smartphone. The NFC tag contains a Citizen description with a unique Passport and a Location containing the IP address of the display. The Citizen description of the Smartphone only contains a Passport as a Location is not needed. The Smartphone's System specification defines an orientation Interface with an EndPoint that can provide pitch, roll and yaw information from the Smartphone.

The display shows a 3D model of a museum artefact which slowly rotates around its y-axis in order to give a 360-degree overview. When a user approaches the display and scans its NFC tag with the Smartphone, a connection is established between the Smartphone and the display. After Passports are exchanged the display decides to explore the System specifications of the Smartphone. Once the display finds the orientation Interface it requests the Smartphone to send all available orientation information from that moment on. The display then uses the orientation information and gives the user full control to turn and rotate the presented 3D model by physically turning and rotating the Smartphone.

This prototype is just a simple demonstration. However, once System specifications are defined, possibilities are endless. For example, the prototype can be extending with actual artefact on display also fitted with an NFC tag. When these NFC tags refer to a database system, this allows information to be pushed to (e.g. comments or feedback), or pulled from (e.g. artefact description), the database system. It could even let users store and carry a virtual representation of an artefact on their Smartphones to the display in order to explore it in a 3D virtual environment.

4. DISCUSSIONS

In this paper, we provided the motivation for a framework that facilitates the emergence of complex systems within the museum environment. Based on the motivation, we have created a framework that can support the identification of entities within a community of people, artefacts and devices. The identification and assignment of unique IDs and the discovery of technological capabilities of entities within this framework will allow rapid development on top of the framework. Due to the decentralised design of the framework, existing systems can easily be extended, or incorporated in new settings without having to redesign the entire system.

The framework adapts to dynamically changing environments where many interactions occur between a wide varieties of users, as such, the framework is particularly suitable for museums. However, in order for museum visitors to become part of the museum infrastructure using their own Smartphones, they need to install an application. How to get visitors to install this application without breaking the flow of their museum visit is an important question. Preferably this activity should be made part of their visit.

The framework is also applicable in different environments and could, for example, easily be used for interactive installations in galleries, libraries or archives. Additionally, by using the EndPoint's address directing users to a video or audio source, the framework also allows for streaming video or audio data.

5. CONCLUSION AND FUTURE WORK

Overall the framework proposed in this paper aims to change the museum environment into a complex system of interconnected entities. It allows elements within a museum environment to be uniquely identified and provides the means to discover, and make use of, the technological capabilities of each element. By first defining the individual elements and provide the means to link them together, the framework facilitates new interactions and allows the elements to generate, manipulate, and exchange information.

Currently the framework supports communications through wire(less) network connections. Extending this by implementing support for Bluetooth and Wi-Fi Direct connections will increase the flexibility of the framework. Additionally the framework could be tested in combination with other technologies, for example interactive displays or low-level hardware. For example, visitors could physically rotate artefacts on display instead of a virtual representation, or interact with a floor plan presented on an interactive tabletop, controlling a 3D view on their mobile phone at the same time.

Now that we have a framework for developing engaging experiences and social activities, the focus of our future research will be to build on top of the framework new engaging exhibits that facilitate social and engaging interactions, from which we could perform user studies that will pave the way for designing future museum environments.

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DIGITAL ARCHIVE SYSTEMS USING CMS AND GALLERY TOOLS – IMPLEMENTATION OF ANTHROPOLOGICAL MUSEUM –

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KEY WORDS: Digital Archive, Digital Museum, Anthropological Museum, Metadata schema, Contents Management Systems

ABSTRACT:

Recently, we have good opportunities to integrate various digital collections and archive systems using loosely coupled and meaningfully connected hyperlinks from various view points of cultural, social and technical aspects. In this paper, from technical view points, we present our implementation of digital anthropological museum using CMSs (Contents Management System) and gallery tools. Firstly, we have a brief comparison of digital archive software including popular CMSs. Recent years, Museums, Libraries and Archives (MLA) are making efforts to provide various digital collections and born-digital information by using digital archive systems. For example, major national libraries and long-term preserving organisations, such as IIPC (International Internet Preservation Consortium), gather and preserve huge amount of web pages, and curate them using web curator tools. Secondary, we propose a metadata schema for digital collections in "*the Anthropological Museum of Nanzan University*", which is based on the guideline of museum objects. Our proposed schema based on XML metadata formats like URI/RDF/MODS. Finally, we show the system architecture of digital anthropological museum and implementation of three different prototype systems based on different CMSs add-on modules and other related software. From 2005 to 2012, we have 1776 digital collections with 74 metadata attributes and 40,000 ethnographic photographs without metadata, at present we store 277 digital contents having detail values into our prototype of digital museum system. Using interfaces of prototype systems, we also introduce workflows of museum collections including content rights management.

1. INTRODUCTION

Recent years, we have good opportunities to integrate various digital collections and archive systems using loosely coupled and meaningfully connected hyperlinks from various view points of cultural, social and technical aspects. Especially, Museums, Libraries and Archives (MLA) are making efforts to provide various digital collections and born-digital information by using softwares of digital archive systems in (Yoshimura, 2012).

For example, major national libraries and long-term preserving organisations, including IIPC (International Internet Preservation Consortium, http://netpreserve.org/), collect and curate huge amount of web resources, and preserve contents in web archive systems. Various types of digital contents, such as text, images, movies and other data types, are stored into digital archive systems, and key technologies are long-term preserving storage, database management systems, information retrieval, web services and others (Kawano, 2008; Kawano 2010, Kawano 2011, Kawano 2012).

In this paper, from technical view points, we focus on how to develop the digital archive systems in order to organise various digital collections with metadata, documents, pictures and movies. We propose a metadata schema for digital collections in "*the Anthropological Museum of Nanzan University*" and present our implementation of digital museum using CMSs (Contents Management Systems) , gallery tools and other related software.

In Section 2, we make a short summary of digital archive systems, CMSs, related software and curator tools. We have a brief comparison of various digital archive software including popular CMSs.

In order to administrate and search digital collections, various CMSs of database applications play an important role. CMS supports an archiving work flow in order to index, search, manage and archive various kinds of digital contents totally. Dspace (http://www.dspace.org) is one of famous software in order to construct open digital repositories. The mashup technology is also important in order to integrate different information resources in CMSs by using standard APIs.

In Section 3, firstly we design our metadata schema for collections in "*the Anthropological Museum of Nanzan University*", which is based on the conceptual reference model defined in "International Guidelines for Museum Object Information" (http://icom.museum/guide.html) and (International Council of Museum, 2011). We design XML metadata like URI/RDF/MODS (MODS Editorial Committee, 2010). Secondly, we present the workflow and system architecture of digital museum. We validate proposed schema by using the MSXML parser provided by (Microsoft, 2011).

In Section 4, we introduce several prototypes implemented from 2005 to 2012. First prototype digital museum is based on Joomla! and some other modules, later we reconstruct second and third prototype systems of digital museums based on Drupal and related packages of album/gallery and annotation tools. In 2011, we implement digital anthropological museum by using Drupal 7.8 on Ubuntu 10.04 LTS. At present, we store 2,054 pictures of museum collections and also associated pictures with csv file of metadata. In our previous paper (Kawano 2012), we shortly introduce the prototype, but we focus on the interfaces for management of museum collections in this paper.

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2. DIGITAL ARCHIVE TOOLS AND CMS

In this section, we introduce a brief summary of various digital archive tools for museums, libraries, archives and web archives. We also present a simple comparison of archiving systems including CMSs.

2.1 Digital Library and Digital Museum Software

From the view point of a software license, several digital library systems are useful, such as *Greenstone*, which is introduced in a book *greenstone*. In the Greenstone tutorial exercise (http://wiki.greenstone.org/gsdoc/tutorial/en/greenstone_to_dspace.htm), there is how to export a Greenstone collection in a form suitable for DSpace. DSpace is also a well-known digital library management tool using various types of academic repositories (Duraspace, 2012). The web site introduces *Digital Collection Builder* (Canadiana, 2012). Generally speaking, these software systems provide same kinds of functions:

- Management of digital collections
- Multimedia data, including common document formats, pictures, movie files and commonly used document formats
- OAI (Open Archives Initiative Protocol for Metadata Harvesting） metadata harvesting protocol
- Standard metadata formats, such as Dublin Core, MODS, and EAD
- Functions of importing and exporting metadata from/to different archive systems

In order to meaningfully integrate information resources stored in different archive systems, it is a first important step to utilize standard metadata formats, document formats, information exchange protocol and other functions.
In the web site of BeanWorks, a brief list includes "Comparing Digital Library Systems" (http://beanworks.clbean.com/category/technology/software/open-source/) such as digital asset management systems for digital libraries and open source software. "The Museum Association of New York" (http://manyonline.org/resources/collections-management-software/) also provides the list of management software.

2.2 Web Archive and Curation Tools

National libraries, national archives and consortia of organizations construct and maintain web archiving systems in order to preserve various web information, which are collected from both of surface webs and hidden webs. Internet Archive is a well-known service, it provides open source software for crawling, archiving and maintenance of web collections.

Firstly, *web crawlers* such as Heritrix, HTTrack and Wget, are the most basic tools for collecting web pages. Web crawlers simply collect HTML/XML web pages sequentially instead of browsing. They also gather metadata such as accessed/modified times, MIME/encoding types, and content length/structure, style sheets, JavaScript, word/pdf documents, pictures, and movies. Moreover, in order to reduce and optimize the load balance of web servers globally, advanced web crawlers have a function of distributed scheduler for gathering web contents from multiple web servers.
However, it is not possible to preserve time consistency of web contents, hyper-links inside a web server and hyper-links between different web servers. Therefore, in order to collect contents from deep web and hidden web, which are provided database systems, various techniques of database archiving and transactional archiving have been developed.
Secondly, *web curation tools* are important for constructing web archive systems. A suite of web curation tools and WARC (Web ARChive) format as ISO 28500 standard are accessed from IIPC (http://netpreserve.org/software/downloads.php). The NDIIPP Partner Tools and Services Inventory (http://www.digitalpreservation.gov/tools/) is also useful lists.

- Heritrix: an open-source, extensible, Web-scale, archiving quality Web crawler
- NutchWAX: a tool for indexing and searching Web archives using the Nutch search engine and extensions for searching Web archives
- Wayback: a tool that allows users to see archived versions of web pages across time
- Web Curator Tool: a tool for managing the selective Webharvesting process is designed for use in libraries and other collecting organisations
- Xinq (XML INQuire), a search and browse tool for accessing an XML database

2.3 Comparison of CMSs

On constructing suitable digital museum, library and archive systems, it is effective to utilize CMS and to integrate various add-on modules and related software. There is a research paper of performance analysis of CMSs in (Patel, 2011, Doulamis 2008), we make a brief comparison of major CMSs and additional modules. Using feature of web site CMSmatrix (http://www.cmsmatrix.org/), we compare popular CMSs, including Drupal, Joomla!, Wordpress, XOOPS and Zikula, from several view points of system requirement, security, support functions, ease of use, performance, management, interoperability, flexibility, build-in applications and commerce.

	Drupal 7.12	Joomla! 2.5.4	WordPress 3.3.2	Xoops 2.0.18	Zikula 1.2.0
Last Updated	2/16/2012	5/2/2012	5/29/2012	8/5/2008	11/9/2009
System Requirements	Drupal 7.12	Joomla! 2.5.4	WordPress 3.3.2	Xoops 2.0.18	Zikula 1.2.0
Application Server	Apache	CGI	blank	Apache	blank
Approximate Cost	Free	Free	Free	Free	$0
Database	MySQL	MySQL	MySQL	MySQL	MySQL
License	Open Source	Open Source	Open Source	Open Source	Open Source
Operating System	Platform Independent	Platform Independent	Platform Independent	Platform Independent	Platform Independent
Programming Language	PHP	PHP	PHP	PHP	PHP
Web Server	Any	Any	blank	Apache	Apache

Figure1: Comparison of CMS functions

3. METADATA AND ARCHITECTURE OF DIGITAL MUSEUM

In this section, we propose metadata schema for digital collections in *"the Anthropological Museum of Nanzan University"* and discuss difficulties to edit appropriate and accurate values for metadata schema. Our schema is based on the guideline of museum objects, and we propose XML metadata formats like URI/RDF/MODS. We also propose the system architecture of digital museum and implement prototype systems based on different CMSs, related modules and software.

3.1 Metadata Schema

In order to design a metadata schema of museum contents in the anthropological museum, we mainly focus on the "International Guidelines for Museum Object Information" (http:// icom.museum/guide.html) and "CIDOC Conceptual Reference Model CRM models" (ICOM/CIDD CRM Special Interest Group, 2008).

CRM model defines the relationships of various entities, such as "Man-Made Object", "Production", "Time Primitives" and others. On the other hand, in different metadata of Dublin Core, fifteen basic elements are selected and standardized, we choose following elements in our digital museum system; "*description*", "*date*", "*type*", "*format*", "*language*", "*coverage*" and "*rights*".

Furthermore, the guideline only provides the conceptual framework for managing museum objects. Actually, we have to define metadata attributes of information management and technical attributes of photographs and movies, which are based on other standard metadata formats.

Firstly, we have a brief survey of other standard metadata formats, such as Dublin Core of Dublin Core Metadata Initiative in (Dublin Core Metadata Initiative, 2008), MPEG-7 and MPEG-21 for multimedia contents in (ISO/IEC JTC1/SC29/WG11, 2004). We also consider metadata attributes of photographs based on MPEG and JPEG standards, after that we design our XML metadata formats.

Secondly, in our museum system, we also need multilingual attributes, so we introduce multilingual fields based on MODS metadata schema. A <Object_Name_Information> has child elements <Title_Information>, which have <lang> and <type> attributes. The description in the attribute <lang>, we use ISO 639-2b, *jp*: Japanese, *eng*: English and so on.

Finally, we design following 22 information groups and create detail metadata schema based on some examples of the museum collections.

- Acquisition Information
- Condition Information
- Deaccession and Disposal Information
- Description Information
- Image Information
- Institution Information
- Location Information
- Mark and Inscription Information
- Material and Technique Information
- Measurement Information
- Object Association Information
- Object Collection Information
- Object Entry Information
- Object Name Information
- Object Number Information
- Object Production Information
- Object Title Information
- Part and Component Information
- Recorder Information
- Reference Information
- Reproduction Rights Information
- Subject Depicted Information

For example, "Condition Information" has categories of "Condition", "Condition Summary" and "Condition date", we extend these categories for administrators and add several attributes, "Receiving Date", "Transportation", "Receiver" and "Return Date". In the information group of "Image Information", we need more detail attributes, such as Title, Image Reference, Keyword, Comment, Medium, Film Instrument, Artist, Film Date, Width, Height, Size, Size Unit, Film Place, Film Latitude Longitude, Photo (including horizontal and vertical resolutions and bit depth etc.) and so on. Initially, we propose and design a metadata schema with 102 attributes presented in Figure 2, and we validate our prototype schema by using the MSXML parser (Microsoft, 2011), which provides extension functions of DOM, SAX, XSLT and others.

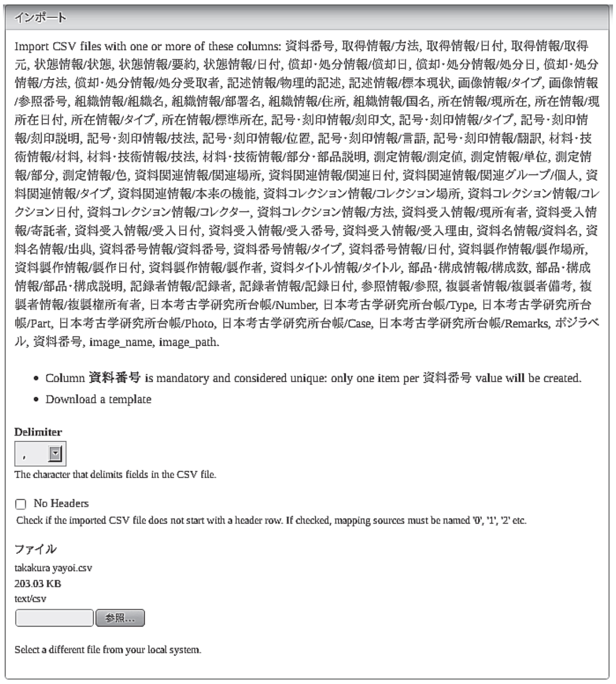

Figure 2: Interface of importing CSV file with metadata

3.2 System Architecture

In Figure 3, we show the conceptual architecture of the museum CMS, the user send a query to the server and the contents management system retrieves various data, such as text, photograph, metadata and layout from different databases, the system dynamically creates a web page based on a user's preference. The granularity of information depends on the grant of users, such as administrators, researchers, guests and so on.

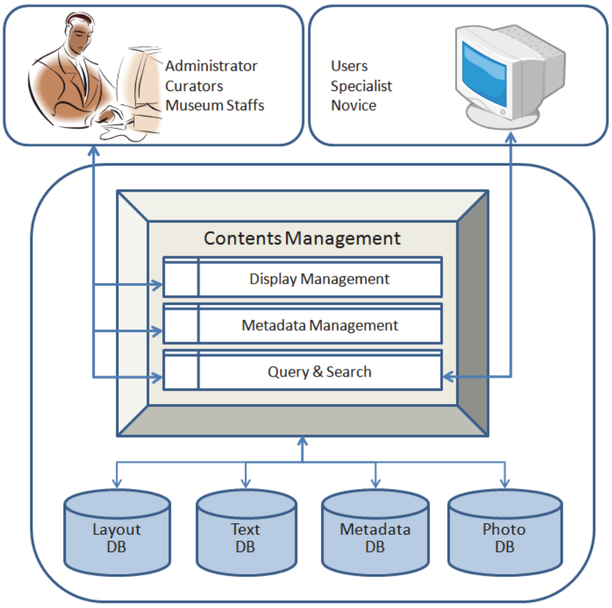

Figure 3: Conceptual framework of museum archive

4. IMPLEMENTATION OF DIGITAL MUSEUM

In this section, we present three different prototype systems of digital museum developed from 2006 to 2012. At present, we enter 2054 digital contents and a metadata CSV file in our system. As we discussed in previous section, we propose 102 attributes, but it is not easy to investigate several attributes by curators in the museum. Furthermore, 1776 contents don't have sufficient metadata values. As a result, we store 277 collections having detail metadata values in 74 attribute fields into our present prototype system.

4.1 Prototype Systems based on Joomla! and Drupal 5

As we presented in Section 3.3, there are various CMSs, such as Drupal, Joomla!, WordPress, XOOPS and many others.In 2006, we develop a first prototype museum system having photo gallery by Joomla! 1.0.11JP and related module software presented in Figure 4. We had a comparison of accessibility between museum CMS and the original museum web site, the performance of CMS is better than the original web site from various view points, such as contrast of colours, stylesheet of layout design and control, design of link navigations, W3C standard descriptions, consistency of hyperlinks and etc. However, our system does not satisfy the conditions of “Double-A” of “Web Content Accessibility Guidelines 1.0” (W3C, 1999).

In 2008, in order to improve the usability of our previous prototype system, we reconstruct digital archive by using Drupal 5.10. The top page of gallery shows a few collections having a part of attribute values.

In this second prototype system, in order to provide the annotation function, we compare several tools and web sites, such as PhotoStuff, M-OntoMat-Annotizer, Taggify and others, but it is so difficult to integrate other different modules in Joomla!. Then we move from Joomla! to Drupal in order to construct the museum archive based on the combination of Drupal and related packages of Gallery2 and Fotonotes annotation module.

Figure4: Top page of museum archive based on Joomla! and Gallery 2

When we construct the museum archive, we consider the stability and extensibility of the system, and we select Drupal (drupal-5.10.tar.gz) and Japanese module (D_ja_resource _kit_5__7_009.tgz). In order to support annotation functions of photographs, videos and other content, we select several modules of “Gallery2” (gallery-2.2.6-developer.tar.gz), “Fotonotes” (fotonotes-5.x-1.1-beta6.tar.gz) and other tools into the Drupal. The detail environment is as follows:

- Ubuntu 7.04
- Apache 2.2.3
- Database (MySQL 5.0.38)
- PHP 5.2.1
- Drupal 5.10
- Gallery Developer 2.2.6
- Fotonotes 5
- Image module 5

We stored 173 digital collections into our digital museum system, and we use 74 metadata attributes, detail attributes are presented in Figure 2.

4.2 Prototype System based on Drupal and modules

In the second prototype system, we constructed digital museum based on Drupal 5 and Gallery2, but we have newest version of Drupal 7 in 2011. It provides the function of image management using standard add-on module of “*Views*” in Figure 5.

Figure 5: Views module in Drupal 7

Therefore, in third prototype system, we adopt “*Views*” module for TBIR (Text Based Information Retrieval) instead of Gallery2, which is presented in Table 6.

functions	Views	Gallery2
Display with thumbnails	yes	yes
Additional fields	With CCk module	yes
Drupal version	7 or 8	Under 6

Table 6: Comparison of Views and Gallery 2

However, it is not possible to create additional attribute fields using only *Views* module, then we furthermore need to implement a core module of "*CCk*" in order to create metadata scheme for pictures.

By the way, staffs in the museum are continuing to have surveys of museum collections in detail, however they are not so familiar with XML database, we provide two importing interfaces "import_museum" and "import_no_metadata", which are presented in Figure 7. A simple sketch of a workflow in digital museum is presented in Figure 8.

インポート	説明
import_museum	人類学博物館資料を取り込みます
import_no_metadata	メタデータが無い画像資料の取り込み用
Node import	Import nodes from CSV file.
User import	Import users from CSV file.

Figure 7: Two importing functions with/without metadata

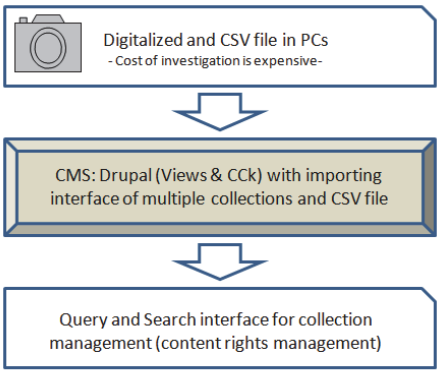

Figure 8: Simple workflow of contents management

Next, when administrators select "import_museum" in Figure 7, they can upload CSV formatted metadata file with detail attributes presented in Figure 2. As we stated in the previous section, we define 74 attributes in the schema of metadata in order to management museum collections.

Administrators can import CSV formatted metadata using "import_museum", and import photo data without metadata using "import_no_metadata". Then, the master file of museum collections are created using CSV format at present.

Actually, administrators can control processes in the museum using search interface, for example, museum management information exist in the database presented in Figure 9. After entering a keyword "need to repair" (in Japanese) into the query box, results of several collections including"1-0393 J-180 IIC-263" and others are displayed.

On the other hand, one of results with "not need to repair" (in Japanese) in an attribute of "Condition Information" is presented in Figure 10. After clicking "Edit" tab an editing interface is displayed in Figure 11. Attributes for contents right management such as "Acquisition Information" are also included in this interface. Finally, in 2011, we try to reconstruct digital museum by using Drupal 7.8 on Ubuntu 10.04 LTS. At present, we have 2,054 digital collections and metadata csv files. However, 1776 contents don't have enough metadata, we store 277 collections having detail attribute values in 74 fields. As a result, during several years, we define metadata for 104 collections, but it is very hard to create appropriate and accurate metadata attribute values. This kind of cost for investigation and management is usually very expensive.

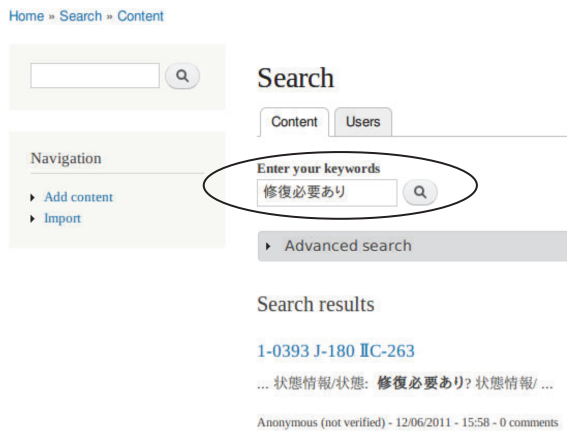

Figure 9: Search for management of museum collections

5. CONCLUSION AND FUTURE RESEARCHES

In this paper, firstly we have a brief survey of various digital archive systems, including digital museums, digital libraries and web archiving systems. Secondly, we have short introduction of prototype systems of digital gallery in "the Anthropological Museum of Nanzan University". From 2005 to 2012, we have developed three different prototype systems using Joomla, Drupal and related modules.

Next, in order to organize various collections with metadata and photographs, we propose metadata attributes and design XML metadata formats and system architecture. Furthermore, we present our prototype systems using Joomla! and Drupal, which has 277 digital contents with 74 metadata attributes, for curators and research staffs in the museum. During several years, we tried to implement advanced functions of annotation function and image retrieval functions in the digital museum.

Finally, the museum collection consists of more than 40,000 ethnographic photographs including the landscape, portraits, ceremonies and others. In near future, we are planning to store various photographs and implementing the similar image search function of those photographs stored in the system.

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Figure 10: Detail results including all metadata attributes

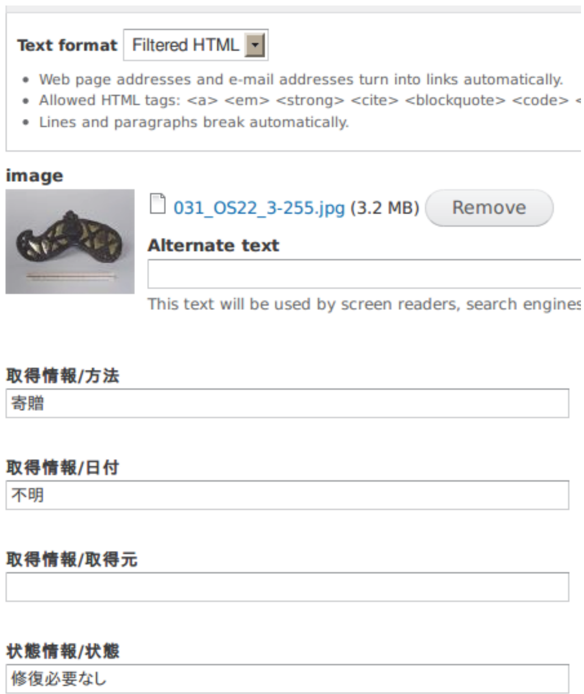

Figure 11: Edit and modification interface

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RADIOGRAPHY OF THE PAST – THREE DIMENSIONAL, VIRTUAL RECONSTRUCTION OF A ROMAN TOWN IN LUSITANIA

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KEY WORDS: Radio-Past, Radiography, Virtual Reconstruction, 3D Modeling, Landscape Reconstruction, Roman Architecture, Lusitania

ABSTRACT:

The European project, “RADIO-PAST” was launched in 2009 within the Marie Curie framework “Industry-Academia Partnerships and Pathways”. The project aims to join resources and different skills to tackle each possible aspect connected with "non-destructive" approaches to understand and reconstruct complex archaeological sites. The consortium of 7 partners has chosen an "open laboratory for research and experimentation” in and around the abandoned Roman site of *Ammaia* in central Portugal, but some research activities are carried out by the partner institutions in different areas of the Mediterranean and continental Europe. This paper describes the various methods and procedures which were used to undertake the three dimensional reconstruction of this Roman urban site in Lusitania.

1. INTRODUCTION

1.1 Introduction

The former Roman town of *Ammaia* in central Portugal serves as an ideal test site to apply state-of-the-art technology for non destructive surveys uncovering the remains of the complete settlement, due to its exceptional condition of preservation.

Figure 1: Birds Eye View of Ammaia

Ammaia was founded at the beginning of our era and was definitely deserted by the time of the arrival of the Arabs in the 9th century. Its intra-mural and suburban areas are now almost free from modern construction and as the site has well preserved underground structures (stone foundations, walls, floors...) it is ideally suited for a wide range of non-invasive investigations, enlarging the database of small-scale excavations in an exponential way. Since 2000 geoarchaeological research by interdisciplinary teams of archaeologists and geomorphologists from the universities of Évora, Ghent and Cassino have achieved very intensive fieldwork here, integrating traditional excavations and ground truthing with large scale geophysical surveys, some aerial photography and GIS-based data processing. Especially since 2009, when the European Marie Curie project “Radiography of the Past” was launched and *Ammaia* was chosen as an open laboratory for research and experimentation, more intensive fieldwork allowed to reveal the full plan of this Roman city. Especially the evidence from geophysical survey, combined with stratigraphic and geomorphological observations, allow excellent study of the ancient urbanism, at the same time limiting the necessity for grand scale and costly excavation procedures, allowing a 3D view of the Roman townscape and opening prospects for the sustainable touristic exploitation and cultural validation of a complex site.

Figure 2: Forum of Ammaia

The obtained total coverage data in the form of Magnetometer and Ground Penetrating Radar Images and interpretations are used to approach a complete virtual reconstruction of the town and its surrounding landscape. The visualization of the geophysical results are approached by referencing the existing data with better preserved sites of the region comparing similar structures and dimensions, aiming to simulate local architectural local and details of decoration. The methods involved in such virtual reconstructions are multifarious and have to be adapted to the special characteristics of this site. Procedures which had been developed and tested over the past years elsewhere are being applied and refined while other new techniques had to be developed to suit the necessity of this project. The work flow as well as the main fields of activities shall be described hereafter.

2. WORKFLOW AND FIELDS OF ACTIVITY

2.1 Data acquisition

Typically the data used during reconstruction projects is furnished by the scientific institutions involved in the project: documents, maps (old and new), pictures and images from archives, excavation reports, aerial photography, LIDAR (Light Detection and Ranging), GPR (Ground Penetrating Radar), ground magnetic survey data, etc. and their interpretations by geophysicists and archaeologists.
Further approaches of digitalisation include photogrammetric geometrisation. With the aid of current software and a series of images taken from several sides of an object the creation of accurate geometry is possible without applying markers or circumstantial measurements. This procedure can be utilized in case of original artifacts of any size as well as aerial vistas.

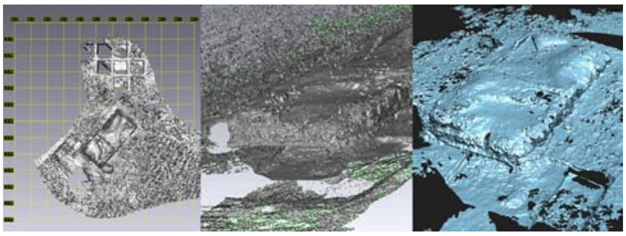

Figure 3: Laser scan of the Forum Temple

2.2 Archiving and data pre-processing

As part of the archiving activity a first processing of raw data from photogrammetric surveys (images) and scans (3D point clouds) is achieved. To acquire high-quality 3D models for further steps in reconstruction projects, raw survey data is processed with different programs; the extraction of textured models with different geometric resolution is usually one of the main issues to decide, depending on the environment where the model is used or placed. One special procedure was established to suit the need of a large online database, where high-resolution scanned objects had to be reduced to 1% of their original density, while still preserving all of their visual qualities.

2.3 Archaeological databases

Due to the fact that several archives started to digitalize their archaeological finds, the need to present this data in an ordered and accessible way to a broader research community and the public is increasing. The scanned objects are displayed on the Internet. To display this media on various platforms, viewers like Adobe flash, 3D-PDF or html 5 are used. Previews of these objects are presented in a lightweight format to make them accessible to all hardware devices.

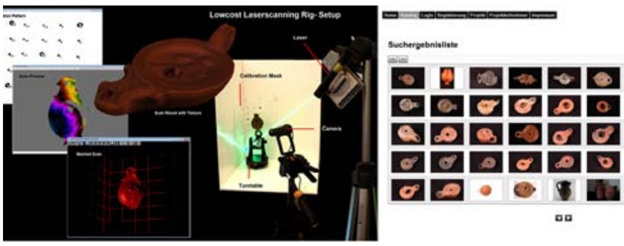

Figure 4: Data Acquisition and final result of a 3d Database

Accurate copies of the scanned data can be accessed by registration in the database and after a download used for ongoing research. By developing a special procedure we are now capable of processing great amounts of items within comparably short time. This digital archiving activity was started in 2011 for the huge database of objects present in the archaeological laboratory and museum of *Ammaia*. Although meant as a research instrument, part of the scanned material, consisting essentially of well preserved objects such as *stelae*, architectural decoration, pottery, lamps, glassware, etc., can be of great use for the virtual town reconstruction.

2.4 GIS – data integration

To combine data used in large-scale reconstruction like the re-modeling of urban settlements and towns, GIS systems are being used. Various georeferenced cartographic and topographic information was collected and assembled to construct a visual database which is used in the particular task of reconstruction. Topographical data like DHM (Digital Elevation Model) and DTM (Digital Terrain Model) is needed for the generation of the virtual environment, which is further modified to achieve an approximation to the state of the desired period. To accomplish these tasks specialised terrain simulators and editors are used to calculate processes of erosion and flow of water. The results are displayed in a fractal geometry, producing a highly realistic and natural appearance. A further task is the insertion of historical maps which can be used to approximate various historical landscape features like river courses, streets and settlement boundaries, including some of the archaeological and geomorphological field data merged via expert knowledge present in the multidisciplinary team. In this way a first base for a visualisation model of the terrain and landscape around *Ammaia* was achieved. This model needs to be further refined in the future once more data, such as from palaeo-ecological and additional geomorphological research, are available.

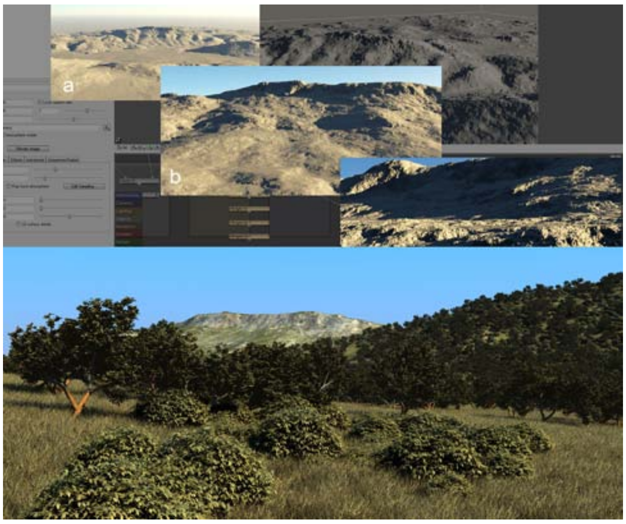

Figure 5: Digital Terrain in various stages of the editing process

2.5 Process of reconstruction

Cultural landscape, buildings and artefacts are digitally recreated or their scan incorporated into virtual environments to present them in their presumed original context. Through constant consultation and discussion between the virtual reconstruction team and the archaeologists authenticity and correctness of the models is ensured. With the help of excavation plans, building remains and unearthed artefacts, the development of comprehensive models of ancient life is sought. The presentation of towns or smaller settlements and the use of the surrounding environment by their inhabitants, building typology for representative buildings as well as for vernacular architecture is recreated. To increase the detail of singular buildings and complexes and to show functionality of interior space finds of the site are displayed at their presumed position. Very often the finds of one particular archaeological site are not sufficient enough to allow for a comprehensive reconstruction. In this case data has to be obtained by comparative research, by using information from sites of the same period, geographical region and importance. For the site of *Ammaia*, the Lusitanian context and in particular data from well excavated parts of the provincial capital *Augusta Emerita* and the extensively studied site of *Conimbriga* are of particular relevance, as are in more general terms data pertaining to excavation sites from all over the Iberian peninsula. To understand questions of operating cycles, effectiveness and the correct use of ancient tools and certain Roman machinery (pumps, lifting devices...), functional presentations are devised and simulations carried out.

Figure 6: Digitalization of the Forums Temple and a possible Visualisation

3. METHODS

Through several sessions involving archaeologists, historians and other researchers the outline of the project is determined: what scope the reconstruction should have, what kind of material is accessible and which form the final presentation will take. After viewing the material, the first approaches are developed: in case of settlement reconstructions a low resolution model is drawn with settlement boundaries, streets, the space occupied by buildings, etc . Usually also the delineation of public areas with representative buildings, such as the forum and public baths (which are typically better documented) and the rest of the settlement occurs. Also very helpful is the fact, that in the past most architecture, especially houses were built complying to a comparatively uniform code of design, presenting a common tradition of a social class or of a population. To determine these building types archaeologists supply excavation results, images of still existing built examples or historical descriptions and drawings. Also specially designated areas within a settlement, like gardens with outbuildings or fortifications, have to be marked out and drawn in 3D. At this point already a crude 3D model of the settlement exists, which is inserted into a realtime engine, to allow modification and interactive display during further sessions with the archaeologists. This point is crucial in every project, as several questions remain characteristically unsolved, and can be studied in detail with the help of the model and incorporated data like maps, the terrain model and excavation plans. When satisfactory answers have been found, and the layout thus modified, the houses in the scene are textured, to give them a realistic appearance and also the landscape, roads and other features are modeled more in detail. Sometimes the decision is made to show a close-up of certain objects, like a single house or compound. In this case a model with higher degree of geometric resolution has to be created, showing also the interior organisation, like rooms, stairs and corridors. To complete the scene, correct building materials, interior and furniture have to be shown. This is a task which is of similar importance as the quality of the general layout, if the overall result should be scientifically correct. In the case of a short film format, a camera path is created to define the sceneries. According to the camera´s clipping, scenes can be further refined and a storyline can be established. To give a reference to human proportions and to provide a more interesting backdrop, animated human figures and artifacts characteristic for the given time are inserted. On the other hand the material can be used to produce interactive 3D real-time applications, allowing the user to freely move around the scenes and access information on demand. This is particularly relevant here in *Ammaia* as the site has its own on-site museum.

Figure 7: Sketch of Ammaia within a 3D realtime environment

4. TECHNIQUES

4.1 Modeling and texturing of objects

To sketch out ideas for a reconstructed scene a coarse geometry is laid out to be presented and discussed with the scientific partners. Various methods of production are implemented depending on the use for the final format. Accuracy and authenticity is crucial to obtain a high quality, together with the documentation of the resulting objects. When the desired level of detail is achieved, the process of texturing (mapping images onto the surfaces) is applied.

Figure 8: Detailed visualisation of roman roofing

A wide range of software is used for the construction of different items and demands highly skilled personal to ensure a high quality output.

4.2 Landscape visualisation

Incoming data from GIS applications were transformed according to the needs to achieve a historical accurate simulation based on manually driven construction methods. The best available technology to output a highly realistic terrain is a fractal approach. The detail of the geometry is adapted depending on the distance to the virtual camera. With this method replicas of millions of items (boulders, trees, houses, etc.) can be spread over the landscape. Certain terrain features like streets, urban boundaries, agricultural land-use or waterways can be defined by simple maps possessing RGB and gray scale values, which are called splat-maps. The ease of use of these splat-maps is one of their advantages, allowing to assemble the information as a simple image which can be edited by the non computer-graphic specialist members of the project team.

If available, LIDAR data can also be used to filter and discard various recent features like vegetation growth and modern construction, allowing in some cases the detection of archaeological remains. Apart from the archaeological interpretation of data from geophysics survey and excavation, aerial images taken from airplanes were used to build geometry without the cost-intensive and laborious procedure of a LIDAR scan with the use of photogrammetry. Fluid simulation was applied to visualise realistic water and simulate river flows of the river Sever and its tributaries.

As no high resolution LIDAR coverage data were available for the *Ammaia*-site we had to make use of a dense DGPS survey which revealed not only the current microtopography in sufficient detail, but eventually helped in filtering out modern elements in the landscape, such as current vegetation and agricultural terracing. Together with the geomorphological survey data they provided a crucial base for the simulation of the early Imperial Roman topography of the area, easily including all elements of standing architecture visible above ground today, such as parts of the city defenses and excavated building structures.

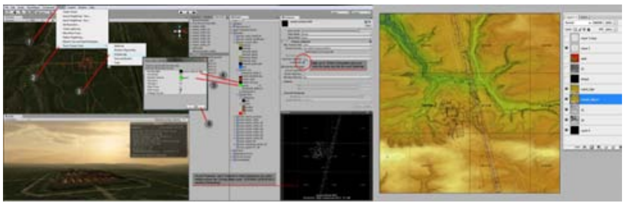

Figure 9: Topographic data editing environment

4.3 Character creation and animation

Still in process, as part of the visualisation of early Imperial *Ammaia*, is the insertion of characters and animations. Humanoid and non-humanoid 3D- models are being created with a toolset specialised for organic construction. Depending on the needs this process can start up from a skeletal phase building up volume by applying muscular systems and ending at the texturing process.

When the desired shape of a model is reached, a kinematic bone structure is inserted with a mesh-binding which allows animation of various parts to proceed. The results can be used for highly detailed visuals as well as crowd animations to enliven reconstructed sceneries, adapted here to the specifics of a Roman or Romanized town and suburban population with a strong link with the countryside and its exploitation.

4.4 Motion-capture

The in-house motion-capture system at 7reasons consists of a magnetic suit, which allows an actor to perform freely in every environment. This can be used to drive a virtual character constraining him to the movement of a specialist or an actor performing in this suit. Optical systems are used to reproduce facial and complete body movements as well as gesture recognition. Data cleaning and - preparation must be done in conjunction with the recording to assure smooth transitions in movement and behaviour. Complete capture sessions can be applied but also smaller parts of these sessions can be used to create clips which then are utilised in turn to create a storyline similar to common film editing. These systems are applied to characters within 3D sceneries for movie production and real-time applications of Early Roman Imperial life in *Ammaia*.

5. DOCUMENTATION

The decisions taken during the reconstruction process are documented and commented in online blogs, citing used material, comparative sources etc. This ensures not only a good communication within the project team, but also transparency, retraceability and a scholarly approach to the topics in question. With this proper base the evolution of reconstruction concepts can be published later on in scientific papers. Without these measures most of the work conducted would be rendered meaningless, as the main goal cannot only be to produce attractive images of historic objects and scenery, but to gain new insights and knowledge.

Figure 10: Blog discussion of a suggested reconstruction of Insula X

6. OUTPUT

6.1 Realtime applications

Realtime applications are made for almost all platforms and hardware devices delivering interactive scenery to the spectator inviting him to discover reconstructed sites and information. The long lasting experience of 7reasons in these fields enables us to apply innovative solutions like archaeological sandbox-systems to aid communication between scientists and artists. This principle can also be used to transfer ideas of a project team to a broader audience. The increasing quality of the current game engines will allow us to produce, in the near future, not only realtime but also film footage without the need of rendering. Various productions have been made recently handling large data sets, such as in the project of the German-Raetian limes, where over 170 km of scanned terrain data was inserted. Other successful productions like those about Carnuntum, Marvao, Caerleon and the Austrian limes show that the new trend of realtime media is very well received by the market.

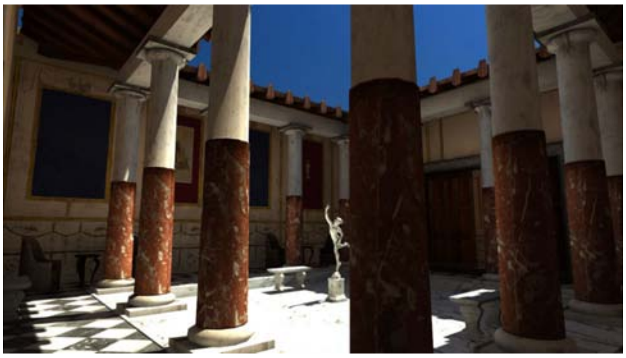

Figure 11: Realtime Walkthrough of a roman Villa

6.2 Short film production

The classical short film production will always be a major part of the media market due to its advantage of linear storytelling. To produce hundreds of thousands of images which are assembled and edited in the post-production phase, we use a considerable number of computers combined to a render-farm.

Figure 12: Screenshot from a test sequence for the planned short film of Ammaia

7. CONCLUSION

A majority of the explained procedures and techniques have been applied to the *Ammaia* project resulting in the first images and models of the ancient landscape setting and large parts of the Roman city. The commitment to create all the necessary visualizations can only be fulfilled with the complementation of the scientific data and their interpretation, which is currently in a final stage. Therefore, the main task of the total reconstruction is still ahead and will be processed within 2012. Many new approaches like the “Three dimensional modular construction system” for interpretation and visualization of archaeological urban environments have been developed and integrated, but also other methods and tools used in former projects could be successfully verified and applied within this *Ammaia* project. The experience gained throughout this work was tremendous and we will gladly share this empirical knowledge in the future.

Figure 12: Realtime editor with drag and drop library of building – block modules

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7.1 Acknowledgements and Appendix

Project Partners: Being an acronym of Radiography of the Past, Radio-Past (2009-2013) concerns a project of the “family” People – Marie Curie Action IAPP (Industry-Academia Partnerships and Pathways), where 4 academic and 3 industrial partners join their resources to develop integrated non-destructive approaches to understand and valorise complex archaeological sites. These partners are: Universidade de Évora (Portugal), Universiteit Gent (Belgium), Univerza v Ljubljani (Slovenia), 7reasons Media (Austria), British School at Rome (United Kingdom), Past2Present (Netherlands), Eastern Atlas (Germany).

A DYNAMIC ONLINE INTERFACE REPRESENTING A POLYVALENT CULTURAL IDENTITY: THE CASE OF CRETE

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KEY WORDS: CULTURAL HERITAGE, CONCEPTUAL MODELING, VISUALIZATION, ABSTRACTION, 3D, CRETE, MEDITERRANEAN

ABSTRACT:

Conceptual models offer the ability to capture several concepts, and more importantly their often complicated relationships, in one single view. When applying this method in order to represent a geographical region's past, this would mean an emphasis on the dynamic structure of the cultural phenomena represented and not on a formalistic evolutionary catalogue of data and de-contextualized information. Especially when dealing with complex and deep hierarchies or intangible notions, a conceptual model can offer an additional level of perceptual understanding. We use the Conceptual Modeling Language (ConML) in our proposed application for the presentation of the main monuments of Crete as a tool for organizing, manipulating, and communicating the large amounts of data such a project entails. Conceptualization and abstraction of information through different levels of detail allows the application to be light and easy to use. Moreover, the ability to switch between different historical periods offers a comparative study of the monuments evolution in time. Thus, we aim at a dynamic representation from the user of Crete's, an island characterized by the Mediterranean's rich and polyvalent historical development, culture.

1. INTRODUCTION

Crete is the largest island of Greece, located to the south, famous for its rich cultural history, which dates back to the Middle Paleolithic age, 128,000 BC. Crete was the center of the Minoan civilization (2,700-1,420 BC). Since then, a large number of monuments has been documented throughout the different historical periods, the most important of which are the following seven (7):
a. Minoan
b. Classical Greek and Hellenistic
c. Roman
d. Byzantine
e. Venetian
f. Ottoman
g. Modern

Our goal is to design an online platform open to the public for the promotion of the cultural heritage of Crete, through a simple, user-friendly intuitive environment. Our prime challenge has been how to manage such a large amount of information over the internet, in a transparent, light and simple way for the end user, in addition to offering the ability to compare data over time, during the historical periods. In order to achieve this we have been using the notion of Conceptual Modeling along with the principles of Model Based Information and Object Oriented Databases. The idea is simple: instead of having all information to its full extent available up front, we break it into nodes, levels of abstraction, called "Levels of Detail", providing the minimum information needed at each given time. Information is stored on each object, each monument, along with its different Levels of Detail. The Levels of Detail that we are using in this platform are the following five (5):
a. Prefectures (administrative units)
b. Cultural regions (often trespassing administrative borders)
c. Settlements - Towns
d. Building complexes
e. Buildings - Monuments

The conceptual diagram on which this platform is based can be seen on Figure 1.

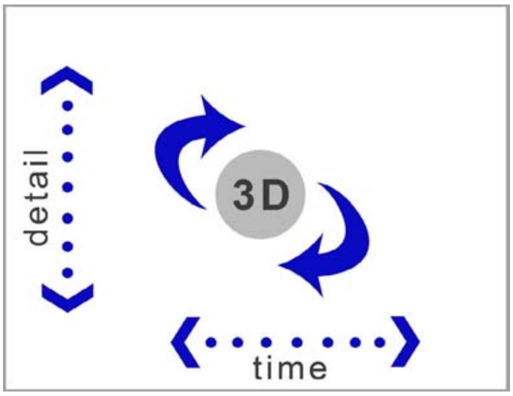

Figure 1: conceptual diagram of the platform

Thus, the originality of the project lies on the following levels:
a. the way it addresses the cultural environment of Crete,

* Corresponding author.

organizing information on a space/time logic varying in degrees of detail according to the user's choice.
b. the way it digitally-technically models/ represents it in the internet.
c. the cognitive model it presupposes regarding the optimal way for the user to gain some knowledge of the region's culture, geography and past.
d. the way it structures the possibility of the user's interaction with the information layers embedded in the platform.
e. the way it groups data and representations produced not just by the project's research team, but also from other institutions.
g. the openness of the platform and its possible application with minor adjustments for the sake of representing other cultural entities.

2. THE PLATFORM

The platform is comprised of the main, central space, where the 3D models are presented, and two scrollable sidebars, one horizontal and one vertical. The horizontal one controls time, and allows the user to switch between the seven historical periods and the vertical one controls the level of detail, allowing the user to switch between more or fewer abstract modes. At the same time, the user has the ability to navigate in real time in the main space around the models, using pan, zoom in/out, rotate, etc. Only when the user reaches the fifth Level of Detail, that of a single monument, he/she has access to all the available related information, which depending on the type of monument could be:

- Photographs
- Architectural drawings (of the existing and/or the restored monument)
- 3D model (of the existing and/or the restored monument)
- Walkthrough animation (of the existing and/or the restored monument)
- Video of the area as it is today
- Maps of the area
- Related documents with more information
- Related links to other websites
- Keywords. Use of keywords allows a cross-reference function independent of the 3D models.

The philosophy of the monument presentation is intended to address mainly non-experts, therefore it follows a more abstract and simplified view of information. It should be easy to use for a visitor who does not have a deep knowledge about Crete and its civilization and would like to be informed at a glance what to visit and where. On a second level, the visitor can focus more on a group of monuments and prepare for his/her visit acquiring more specific information, stored "on" the monument's model itself.

We believe it is crucial to provide the user with the possibility to produce his/her own multiple cultural representations and interpretations of the island's polyvalent cultural, historical and geographical scape. We don't intend to promote a strictly architecture-based limited image of Crete's past, but a dynamic understanding of its hybrid cultural identity, Crete being one of the places where most of the cultures which have developed in the Mediterranean have interfered. In that sense, we don't limit our points of reference strictly based on a 'high culture' agenda; apart from traces of an 'official' historical past, such as the Minoan Palaces and the Byzantine Monasteries of the island, we also include local networks of vernacular settlements (such as the Sfakia region) and places invested with local myths, legends and events or with monuments of past lifestyles, trades etc. (ex. The Tampakaria in Chania). In that sense, addressing history of architecture as part of culture and not just as a catalogue of important buildings per se, we aim at unfolding the ways in which architecture has been developing in Crete as a witness of the inherent cultural dynamics of change and adaptivity as well as tradition and continuity. Sites symbolizing the unity of local culture as well as contested places indexing the dialectics of local and regional conflicts form an equal part of our localized references. This is the way to turn all this information into something engaging with the interests of the cultural contemporary traveler.

The application is currently based on Adobe Flash in order to provide maximum compatibility with most of the major web browsers, to be light and easy to use and to avoid installation of other software. At the same time we are investigating whether technologies such as Unity 3D or SpiderGL can provide a more suitable environment to work with.

The proposed application could take advantage of other related research projects which have rigorously documented and categorized the monuments of Crete, such as the "Digital Crete: Mediterranean Cultural Itineries" (http://digitalcrete.ims.forth.gr), which was implemented under the framework of the Greek Operational Program Information Society (Action 1: Education and Culture, Measure 1.3: Documentation, Management & Promotion of Greek Cultural Heritage) (http://www.infosociety.gr). It is important to keep the application as open as possible so that more monuments and more information for existing monuments can be added regularly.

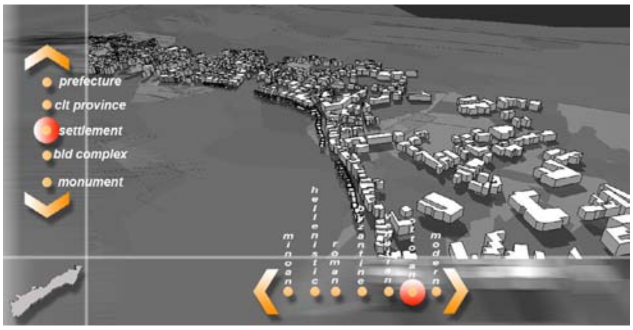

Figure 2: user interface of the platform

3. USING THE CONCEPTUAL MODELLING LANGUAGE (ConML)

In order to begin building our conceptual model, first we have to define our main classes: the class "Object of Interest" and the class "Representation". The fundamental argument on which our model is based is: "every Object of Interest is represented through a Representation". The Objects of Interest can be one of the following five (5) classes, which are Subclasses of the "Object of Interest" class: "Monuments", which can be part of a "Building Complex", which can be part of a "Settlement", which can be part of a "Cultural Province", which can be part of a "Prefecture". Each of these five (5) Objects of Interest can have attributes, such as "Description", "Links" and "Keywords". They must all have a common attribute though, the "Historical Period", which therefore becomes an attribute of their abstract class, the "Object of Interest". The data type of the attribute “Historical Period” is enumerated type and can take a value of one of the following seven (7): Minoan, Classical Greek & Hellenistic, Roman, Byzantine, Venetian, Ottoman and Modern. Since one Object of Interest has to belong to at least one Historical Period, but could also belong to more than one, the cardinality of “1…*” is placed next to the name of the attribute. The class “Representation” has the following subclasses: “Photo”, “Drawing”, “Video”, “Map”, “3d model”, which have various attributes such as “Exterior”, “Interior”, “Resolution x”, “Resolution y”, “Color”, “View”, “Reality”, according to their type. Their common attributes become attributes of their abstract class, the “Representation”, and are the following: “Analog” (type: boolean), “Copyrights” (type: text), “Year” (type: number), “Description” (type: text) and “File Format” (type: enumerated).

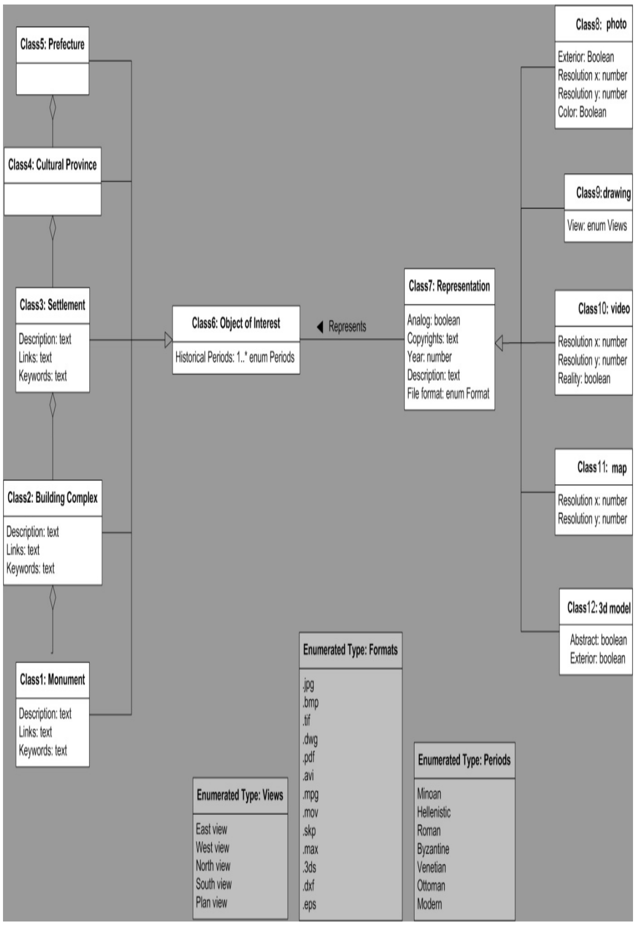

Figure 3: conceptual model using ConML

4. CONCLUSIONS

The primary contribution of the proposed platform is the ability to switch between different historical periods thus offering a comparative study of the monuments evolution in time. Nevertheless, the fourth dimension is exploited here in a more abstract way than other scientific approaches (e.g. Kulitz, Ferschin & Matejowsky) since realism and full detailing is not the goal of this application. Furthermore, its advantages are: the user friendly interface which is addressed towards non experts and its ability to continuously expand with new material regarding either new monuments or new information for existing monuments. Some of the issues we are currently working on are:

- Subjectivity due to abstraction. When information is abstracted, the role of the person who decides which information should be secluded is a key role since it could possibly skew the end result.
- Uncertainty due to lack of information.
- Use of multiple semantic links.
- Interoperability / expansion. The proposed application could serve as a central platform which could be joined by other applications which focus on a more detailed, photorealistic monument representation.
- The possibility to allow a certain degree of participation on behalf of the user(s) on the level of updating the platform. On this level, our research could benefit from such work as that conducted by K. Ntalianis, N. Tsapatsoulis, A. Doulamis and N. Matsatsinis in Cyprus based on the possibilities of crowdsourcing.
- Building Information Modeling (BIM). What can we learn from the structure of information used today in BIM?

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A FRAMEWORK FOR CLASSIFYING INTERACTIONS IN CULTURAL HERITAGE INFORMATION SYSTEMS

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KEY WORDS: Cultural heritage information systems, interaction patterns, taxonomy, digital libraries, information access

ABSTRACT:

With the mass digitization of cultural heritage and the increase of people accessing the digitized memory objects, it becomes crucial to develop meaningful interaction patterns in cultural heritage information systems. This explorative study is based on an investigation of 50 websites from the cultural heritage domain. It derives a framework for classifying user interactions with digital cultural heritage. The framework has two dimensions; the first one is a classification of the interactions and the second one describes their degree of complexity. The strength of this framework is the ability to compare complexity, scope and purpose of interactions across different websites while offering a meaningful vocabulary for discussing different interaction features.

1. INTRODUCTION

Recently, memory institutions face the challenge to broaden access to their cultural heritage material by digitizing it and providing and displaying a digital surrogate online. They need to handle the demand for interoperable metadata and making it retrievable, in the best case across languages and cultures. Moreover, cultural institutions seek for a meaningful presentation in terms of displaying and contextualizing their digitized cultural heritage data. However, in many cases the digital representations do not reflect the context the original artifacts were embedded in which leads to a loss of meaningful information. Therefore, the task is to define purposeful interactions with cultural heritage online and give users guidance to explore new ways in dealing with these digital artifacts. In this process, it is essential to identify the potential benefits of displaying and providing cultural heritage in a digital medium. The goal is to build systems for interacting with memory artifacts that are open to evolve and can adapt to interaction and usage patterns that are not yet foreseeable.

Many recently developed cultural heritage information systems are lacking a strategy for user involvement and purpose of such an engagement. They have striking similarities to cultural heritage search engines suppressing the fact that many users might not be able to express information needs for a cultural heritage artifact in a query. In this domain, supporting serendipity and exploration of the unknown should be a more desirable interaction feature than retrieving known items.

Initiatives like Europeana[1], launched to improve access to Europe's digitized cultural heritage objects and their metadata, are researching and pushing for new interaction patterns and the development of interfaces which allow for rich user experiences with their content. Nevertheless, it is very hard to design interaction patterns in this juvenile area. Some memory institutions are trailblazers in the field of digital interaction but they struggle to determine why certain features are not adopted and users refrain from interacting with them.

This explorative study aims at developing a framework, which enables comparison of different interaction features and their inherited patterns. Consequently, variations of interaction features across different cultural heritage information systems can be mapped in this framework. Moreover, it reflects the state of the art of interaction features implemented in cultural heritage websites and enables the development of best practices and recommendations for advancing interactions in this domain.

By reviewing a sample set of cultural heritage information systems, interaction features are grouped and categorized to reflect the spectrum of interactions available on current systems. To catch the various degrees of complexity in which the features were implemented, an additional dimension is introduced which allows grouping of interactions on an ordinal scale.

The paper is structured as follows: The next section defines the used terminology and background of the study and refers to related work. Section 3 presents the methodology of the analysis. Section 4 introduces the framework of interactions. The paper ends with a conclusion and an outlook on future work.

2. BACKGROUND

2.1 Cultural heritage information systems

Cultural heritage consists of objects created by or interpreted by humans in contrast to natural heritage (Bearman, 2002). These objects are products, which inherit a purpose and are defined by their use (Bearman, 2002). Including intangible objects such as dances or language will explicitly extend this definition.

With the rise of digitization in the last two decades, digital surrogates and their metadata, which reside in information systems online, complement cultural artifacts. Information systems need to be developed which provide novel and innovative ways to experience cultural heritage outside physical institutions, especially as memory institutions move from being gatekeepers to becoming facilitators and mediators of knowledge exchange (Freedman, 2000).

A cultural heritage information system is an information system that collects, stores, organizes, searches and displays cultural heritage objects including their metadata in a digital environment. It needs to answer questions of "*who, where, why, how, when; and what was created, collected, discovered, described, published, and exhibited*" (Bearmann, 2002). This

[1] http://www.europeana.eu

requires the information system to provide interactions that go beyond the common search experience and accommodate contextualization and collaboration. Furthermore, a cultural heritage information system should be transparent about the scope and extend of its collections to facilitate ease of use.

2.2 Interactions

Interaction is a multifaceted and interdisciplinary term with slightly different meanings and intentions across domains. This study follows the definition coming from the Human-Computer Interaction (HCI) field, where an *interaction* includes all engagement between a human and a computer. The term *interaction* consists of all tasks a user can fulfill in a cultural heritage information system including searching, retrieving and browsing items. Furthermore, it includes tasks that support collaborative engagements such as editing a user profile, uploading objects and collaboratively creating collections. This is similar to the view an interaction designer takes on *interactions* which is also commonly referred to as *interaction patterns*: the desire to offer an easy-to-use and successful solution for a common web task or known problem such as logging into an account or adding a tag to a resource (Crumlish, 2009, p. 10). The simplicity and design of such a solution plays a major role in this context where in some cases the size of a button can make the difference. Design implications are of less interest; the behavioral aspects of interaction patterns are the main focus of this study.

In recent research, interaction is put into a broader perspective. These considerations reflect on possibilities interactions offer in a digital environment forming a new medium whose potential is not yet conceivable (Murray, 2011). A paper in the field of visual analytics understands interactions as a process through which knowledge for the user is derived or altered (Pike, 2009).

To the best of the author's knowledge, there are only a limited number of publications dealing with interactions in cultural heritage information systems. Most of these studies in this field are aimed at analyzing the acceptance and usage of a certain website feature with the goal to reveal technical weaknesses and user intentions to derive best practices. Paul Marty for example analyzed user expectations when creating collections on museum sites (Marty, 2011). The focus was on determining to which extend the system features were used and for which purpose. It does not suggest how much these expectations match the actual features and some of the expectations are derived from the use of similar application in different domains.

Furthermore, Liew analyzed information retrieval features and the provided search and browsing capabilities on cultural heritage websites (Liew, 2005). Although this study is already 7 years old and has an explorative nature, most of the findings are still true for many cultural heritage websites. It states for example that many of these sites have a unified interface for all users and offer only limited implementation of multilingual search features. This observation is still valid for recently developed cultural heritage websites.

In the broader context of digital libraries, studies were conducted to better understand user interactions and derive requirements for the design. Here, interactions are influenced by design choices and follow closely the definition of interaction designers given above. One study compared different browsing and search features and their influence on the user's performance. One lesson from the experiment is that poorer design choices are leading to a drop in performance (Zhang, 2008).

Additionally, there is a range of research that describes frameworks to better understand the different dimensions of humans interacting with information. One example is the work of Belkin and Cool who developed a classification scheme for information seeking behavior (Belkin, 2002).

Marcia Bates proposed a cascade of interactions for digital libraries (Bates, 2002). She states that it is important to understand the different parts of a digital library and their interplay. Her model, theoretically dissecting a digital library into strategic parts, suggests that each component of a digital library influences the design of the part built upon. The core component of an information system constitutes of the content and the technical backbone building up on cascading layers. The last layer presents user's expectations and interactions with the system that are influenced by design and technical decisions which are made before (Bates, 2002).

In a much more simplified model derived from Bates' assumptions, it can be determined that every information system (also outside the cultural heritage domain) strives for a seamless interaction between the users and the content. The layers in between - on the one hand the system which enables access to the content in all its facets and on the other hand the interaction patterns and interface functionalities which enable the user to interact - should be as transparent and intuitive as if they were invisible to the user. Figure 1 illustrates this model.

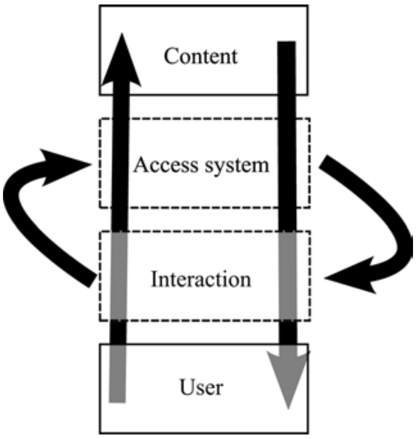

Figure 1. Model of an ideal information system

To the best of the author's knowledge a theoretical framework of interactions within digital cultural heritage has not yet been developed.

3. METHOD

Describing the different interaction patterns and features present on cultural heritage websites is a first step to deeper analyzing them and allowing for comparisons across sites. The cultural heritage domain is in need of a common vocabulary to be able to discuss and evaluate the different features and interactions that are implemented so far.

Due to a lack of formalized frameworks to classify interactions, a content analysis was chosen to determine prevailing engagement options. The qualitative analysis was set out to answer the following questions:

1. How can user interaction patterns and features that are implemented in cultural heritage information systems be grouped and classified?
2. How can the complexity of interactions be described acknowledging that the same feature is implemented in different ways across websites?
3. How can features and subsequently cultural heritage information systems be compared?

A sample set of 50 websites was chosen - all of them fulfilling the definition of a cultural heritage information system as given in the previous section. The goal was to find a wide variety of sites reflecting the whole spectrum of cultural heritage information systems. This purposeful sampling pursues the goal of collecting websites that either stand out in their way of presenting cultural heritage material, engaging the user, being maintained by a well-known authority or being popular for their design and interaction features. For aggregating this list and retrieving sites that meet the requirements, thematic mailing lists, conference websites as well as journals were scanned.

All interaction patterns and features found on these sample websites were listed and afterwards grouped according to their scope, extent and purpose. The result was a classification scheme for these types of websites with regard to their structure, interaction with cultural heritage objects and their collaboration among users.

The scheme was refined with every new website which was analyzed in case a new interaction feature was found. The classification was adapted accordingly. It was found that interactions are very faceted. For example, some websites do have features for social tagging of cultural heritage objects but not all of them were implemented with full sharing options. To compare different features and sites it is not enough to list that they exist but to describe their level of complexity. To address this problem, another dimension was added to the classification that describes the degree of the complexity of each class of interactions.

The following section explains the developed framework in more detail.

4. FRAMEWORK OF DIMENSIONS OF INTERACTIONS

This section describes the result of this study - a framework that was developed based on the interaction features and interaction patterns which were found on a sample of 50 cultural heritage websites.

4.1 Classification of interactions

In a first step, a classification of the different interactions found on the sample websites is developed. This is the first dimension of the framework and it provides a grouping of the interactions into features that are prevailing in cultural heritage information systems.

On a meta-level, all of the interaction patterns deployed in cultural heritage information systems can be broadly subsumed under one of the three following points:

1. Content: This comprises all features that are targeted around experiencing the content such as search, curated exhibitions or deep-zoom features.
2. User: These are features and their inherited interactions that revolve around the user management and user identity such as creating and editing user profiles.
3. Participation: These are all features allowing the user to experience cultural heritage in a personal or customized way alone or in a group of like-minded.

Table 2 shows the taxonomy of interactions with a detailed description of every class. Any user action where the user interactively uses the system can be categorized into one of the 9 classes that are tailored to the cultural heritage domain.

Meta-Class	Class	Description
Content	Cultural heritage (CH) objects	Interaction patterns supported by features related to the pure content aggregated in information systems such as searching full-text.
Content	Curation	Interaction patterns supported by features related to curated content provided by the information systems' authorities, e.g. browsing thematic exhibitions.
User	User representation	Interaction patterns supported by features that help users to represent and connect with each other e.g. create user profiles.
User	User reputation	Interaction patterns supported by features that are related to user reputation such as rating and starring favorite objects, following of other user's contributions across the site.
Participation	Storytelling	Interaction patterns supported by features allowing the user to add their own point of view through directed and chronological narration.
Participation	User exhibitions	Interaction patterns supported by features allowing users to curate customized exhibitions and collections.
Participation	Annotations	Interaction patterns supported by features that allow the user to add additional information to content such as writing comments or other free text.
Participation	Social tagging	Interaction patterns supported by features for adding terms and keywords.
Participation	User objects	Interaction patterns supported by features for uploading, publishing and maintaining users' content.

Table 2. Classification of interaction patterns and interaction features in cultural heritage websites

4.2 The degree of complexity of interactions

When analyzing cultural heritage digital libraries, it is important to understand that the interaction is two-fold. On the one hand, there is the information system as a whole with its different components, on the other hand, there is the user. In an ideal system the user interacts with the aggregated content in a natural and seamless way (see figure 1).

A digital surrogate of a cultural heritage item possesses a different interaction potential than the original physical object. In an online environment, there are more possibilities for interaction compared to the potential in a physical institution. In physical exhibitions, the artifacts are too scarce and valuable to take interaction with them beyond simply looking at the particular item. Within an online information system, three prevailing types of access determine interactions:

Search: All cultural heritage information systems make their collections accessible with textual search. Matching user queries to the metadata of an object lets the user retrieve items. Search is determined by formulating a query, scanning the result list for relevant items and finding results that might answer the information need. The challenge here is that the paradigm of the known-item search common in libraries is transferred to the cultural heritage domain. But many objects, particularly the ones coming from museums, are not sufficiently described by their metadata (e.g. acquisition numbers and dates of acquisition instead of subject headings, keywords).

Browse / Explore: Browsing features are crucial for cultural heritage information systems. They support serendipity and the discovery of unknown resources. For users, extent and scope of collections in these information systems is vague and not transparent. Therefore, innovative browsing capabilities are needed. The more the data is linked (amongst each other or to external resources) and the more its structure is exploited, the more possibilities can be offered to browse and explore the content.

Engage: The engagement level comprises all access points that are created by users adding their own content and view points, collaboratively working on content creation. Additionally, it enables exploration of the content beyond the website's scope. Examples are following enrichments links to Wikipedia or uploading user-generated content and sharing it with friends.
These three access types can be arranged in a hierarchy, where search is the access type, which needs the least amount of interactions between user and system going up to the engage level that can have an infinite number of interactions depending on the complexity of the implemented features. The more interactions are possible, the more complex the information system becomes.

To have a simple classification of interactions is not enough to compare websites and their implemented features with one another. The access type the websites offer needs to be determined and that one is driven by the complexity of interaction. To achieve this, a second dimension is introduced to complement the classification and this one determines the degree of complexity of the interactions and interactive features on a scale of ordinal values (1-5):

1. Content: On the most basal level, there is content in form of digital surrogates, born-digital objects and their metadata aggregated in an information system. With regards to complexity of interaction, this level is mainly characterized by textual search as the most basic form of accessing content; in many cases it is a simple search box. This level has the least amount of interactions.
2. Organization: On the next level, structuring the content by adhering to best practices in metadata standards enables more complex interaction patterns. Consequently, this allows simple browsing and content exploration beyond search. An implementation would be the use of rich, domain-specific data models such as CIDOC-CRM[2] or the Europeana Data Model[3]. An example of the benefits of more structured metadata is the provision of faceted search to reduce the number of results for a query.
3. Enrichment: The next level is any form of enrichment that adds additional information to an object and links it to outside resources. Enrichment provides the user with more entry points for retrieving and exploring particular content and enables the differentiation of ambiguous terms and the identification of named entities and such. The enrichment, structure and metadata level comprise features with limited interactive complexity building upon basic textual search to more elaborate interactions such as facets.
4. Contextualization: The following more complex level is contextualization. The content gets embedded into richer and more diverse contexts. This can mean that users curate cultural heritage objects and add their meaning and interpretation or it can be the provision of storytelling functionalities. At this point, interactions become very complex and get intermixed with the need to set the right incentive for the user to participate. The technical implications for implementing contextualization are very manifold; user-generated content needs to be stored, upload functionalities provided and a quality assurance deployed. Only a handful of websites offer contextualization through user-driven data.
5. Collaboration: The most complex degree of interaction is collaboration. The focus here is on working together in groups and sharing the experience. To implement this, complex group functionalities and rights management need to be set up. Furthermore, to get users to interact with each other requires multifaceted user management and representation features.

Figure 3 shows a model of the interaction degrees and their interplay with the access points including search, browse and engage components. In general, the more complex and user-oriented an information system is, the more interaction features and access points it offers.

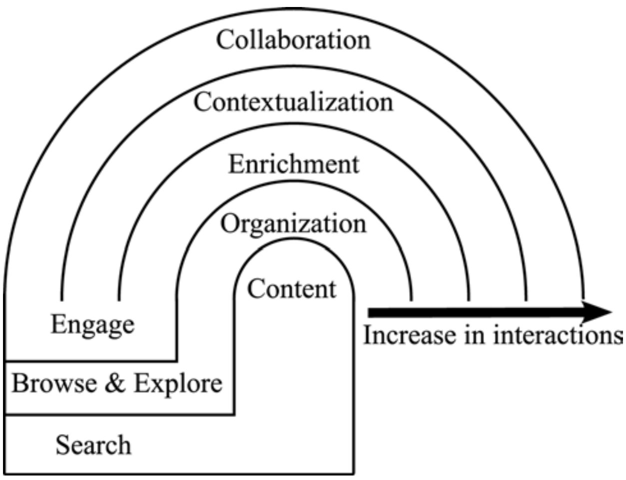

Figure 3. Degree of complexity of interactions with associated access points

This pyramid model shows that with every level the complexity of the interactions and the numbers of possible interactions increase. Every category of interaction in an information system can be analyzed in terms of its inherent interaction degree. The degree of interaction varies greatly, and different characteristics are prevailing depending on the component implemented.

[2] http://www.cirdo-crm.org
[3] http://pro.europeana.eu/edm-documentation

4.3 Combining the classification and the degree of complexity of interactions to a framework

Combining the classification of interactions with their degree of complexity forms a framework that enables comparison and evaluation of cultural heritage websites. It provides a means to express the complexity, degree and variability of interactions on a given site in relation to its access points. The possibility to compare interactions, features and whole information systems on an ordinal scale offers new insights and perspectives in discussing these sites.

Each class of the classification has the dimension of its complexity attached and allows to categorize each feature on a website. The focus of each cultural heritage information system becomes obvious and its implementation can be discussed. Figure 4 shows a radar model of the different classes with their complexity level. The outer rings of the radar represent more interactions than the rings closer to the center.

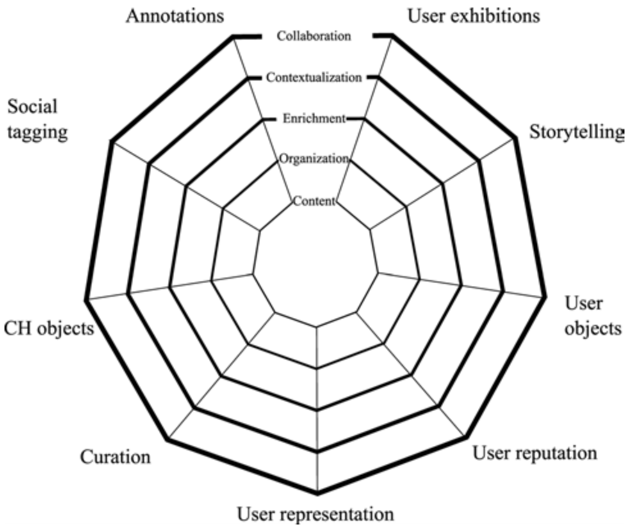

Figure 4. Model of the framework with both dimensions

For example, the interactions subsumed under the *Social tagging* class are integrated into many different cultural heritage websites to provide the user with a means to interact with the content but not all implementations are well engineered. For *Social tagging*, the different degrees of complexity would look like this:

1. Content level: This is the basis for providing a tagging feature; it comprises the tags and an appropriate storage system. In terms of interaction patterns this means: adding and deleting tags.
2. Organization level: The system enables the structuring of tags. This could mean that it stores tags with its appropriate links to the tagged resource and the tagging user. In the literature, this is referred to as the tag-resource-user relationship (Peters, 2009, p. 39). The first and second levels allow the user to search and browse the tags. Common patterns are the distinction between public and private tags and pivot browsing based on the tag-resource-user relationship.
3. Enrichment: The system offers automatic features to ensure qualitative tags. This could mean an auto-completion feature or enrichment of the tags with controlled vocabulary.
4. Contextualization: Users are able to add complex information to the tags like descriptions, preferred terms or links. The system would also allow pivot presentation of different relations among users, tags and resources.
5. Collaboration: The most complex level comprises collaborative editing of tags and the ability to collaboratively determine preferred terms for tags excepting misspellings and outdated terms.

As shown, for each class of interaction the degree of complexity can be determined and a representational point be marked in the grid.

In a next step, a visualization of the differences between websites can be made on the basis of this framework.

One example is a comparison of Europeana's interaction features with the ones of the Google Art Project[4] (figure 5). Both systems offer access to cultural heritage but their scope and intent is very different. Figure 5 shows the radar graph for these two sites. It is quite clear from this presentation that the Google Art project is much more focused on user engagement and involvement. It offers user exhibitions where a section of each picture can be added to a custom collection and be described. Furthermore, each object in the user collection can be contextualized with a Youtube video. Moreover, it is visible that it is standing out in its way of displaying its objects. It offers a deep-zoom feature that makes every stroke visible (CH objects); the project adds an additional layer of experiencing cultural heritage online that goes beyond the common perception of a painting in the museum.

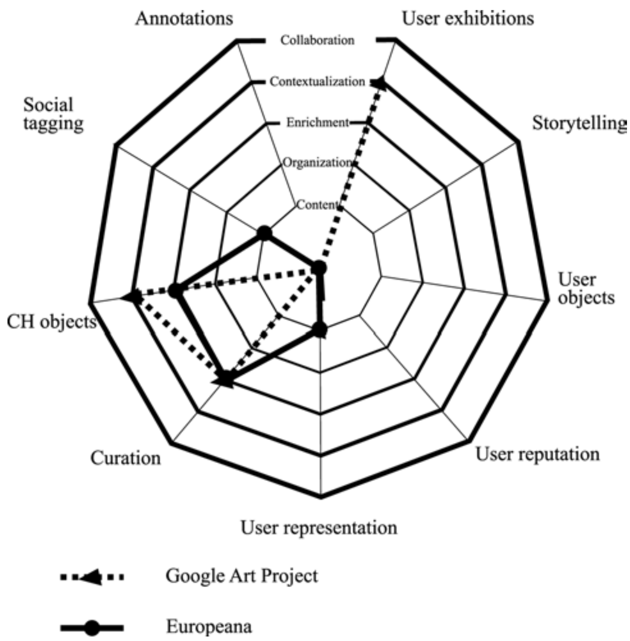

Figure 5. Comparing two websites from the sample based on the framework

Europeana, in contrast, focuses on curation of content and metadata retrieval. User engagement is only provided on a limited basis. User accounts are offered but are not used to support user participation or engagement. Europeana enables users to tag their favorite objects but it does not offer more functionalities than a private bookmarking list. In both projects, user collaboration is not implemented for any of the feature groups.

[4] http://www.googleartproject.com/

5. CONCLUSION AND FUTURE WORK

In this paper, a framework for interactions on cultural heritage information systems is developed. First, a classification of different interaction groups is established and in a second step the degree of complexity of interactions determined. The framework describes the scope and purpose of each interaction and couples it with its degree of complexity. It makes it a beneficial tool for discussing different website, their desired intent and implementation. Shortcomings and implemented features can be challenged, analyzed and as a result improved. Information systems and single features across websites can be compared. The framework acts as a means to determine the focus of websites in the domain and derive best practices for matching interactions with the desired scope and purpose of cultural heritage information systems.

In future work, a quantitative analysis of the 50 websites will follow that determines which interaction patterns are occurring on these 50 websites. Additionally, best practices for implementing interactions and features will be derived from these results.

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3DPUBLISH: A WEB-BASED SOLUTION FOR BUILDING DYNAMIC 3D VIRTUAL MUSEUMS

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

ABSTRACT:

Today museums around the world offer their content through two basic methods: a simple view of their artworks through a content viewer, or through a custom designed 2D or 3D virtual exhibition in which the pieces and the scene are static. This paper describes a 3DPublish tool which represents an alternative to these two static solutions thereby giving the possibility to dynamically manage a 3D virtual scenario (real or imaginary) and the artwork that composes it. This gives the user a most realistic experience through different exhibitions, using various added value methods like storytelling or virtual tours. 3DPublish will facilitate the museum curator's daily tasks and will improve the final results for 3D virtual museum exhibitions. This application was created as part of the Tourspheres project, whose challenge is to explore new measurement systems to reach a more valuable tourist behavior comprehension. But after the experience (presented in this paper as a case study) of creating a custom development for an exhibition for the Kubo Gallery in San Sebastian (SPAIN), the work focused on abstracting all processes to package the 3DPublish tool with the aim that it becomes a commercial solution.

1. INTRODUCTION

1.1 Context

For years, museums curators' efforts around the world focused on providing the public art collections digitally exploiting the latest advances in technology (Heath, 2005). To support these efforts, leading technological research efforts focused primarily on two sources: first the ability to scan the collections of museums through different techniques (3D scanners, high resolution photographs, assembly 360, etc.) (Hess, 2011), (Toylor, 2003) and the second source was techniques representing these works in virtual scenarios (real or imaginary) to make the visitor feel the physical sensation of being in a museum exhibition.

These static solutions were aimed at technological solutions, and provided valuable indicators such as the number of digitized works (Nóbrega, 2012), the type of digitized works (paintings, works in 3D, etc.), the similarity of a virtual scenario, or the amount of semantic information to organize the whole collection (Bonis, 2009). But this situation has changed.

In recent years the user experience in terms of education and entertainment has become the priority, even sacrificing technical advancement in some cases. This was in order to make the user more interested in museums and the cultural heritage they offered. Because this focus has shifted, the style, materials or location where artwork was created is not as important as the story associated with that work (Christopoulos, 2011) and what it represents in the context of an exhibition carefully created on a specific topic.

Furthermore, the current instability of the global economic situation makes many museums around the world discard the possibility of creating a virtual environment to deliver their presentations in an appropriate context (Dyson, 2010), and if they already have a virtual environment created, they cannot afford development to accommodate a new virtual exhibition. Despite this, creating virtual exhibitions is still a profitable idea because museums offering collections information and images on their web sites will not reduce visits to the physical museum, and will likely enhance interest in making in-person visits to the museum (Thomas, 2005). Recent initiatives such as Museums Analytics (Museum Analytics, n.d.) prove the strong correlation between any online activity and real visitation. In terms of profitability it is well known that the benefits of virtual museums contribute to visitation and are noteworthy as far as curators are concerned and in terms of documentation, conservation, research and exhibition (Sylaiou, 2009). 3DPublish allows museum curators to improve their usual processes more easily and therefore to improve their efficiency and profitability.

1.2 Project aims and scope

The 3DPublish main objective is to create a common framework to allow museum curators to create final exhibitions dynamically and independently of their start empty virtual scenario. This means that the curator has the ability to choose one 3D modeled scenario (real or imaginary) or use one of the basic available default scenarios provided by the application. So with 3DPublish the curator will not even need to have a modeled scenario to create a 3D virtual exhibition where a user can move and interact.

A secondary goal involves the ability to manage the contents of that scenario externally, feeding the application with different artworks in digital formats.

Once we have an empty virtual scenario and the artwork, the third goal is to give the possibility to position the artwork along the scenario, including the option to create new spaces (which do not exist in the base scenario) with new walls with different heights and thicknesses in which, of course, it will also possible to place artworks.

To improve the user experience, as related above, is also part of the project scope. Museum curator will be able to create different thematic exhibitions and visitor may choose load which one is more interesting for him. Each artwork may also be associated with an audio piece to complement the information and create a storytelling. Finally the museum curator can create guided tours.

Many online web-based virtual museums have offline background processes for support. However, the entire 3DPublish project will be consumed through a web interface for both the museum curator and the visitors. 3DPublish will allow museums to increase their digital profile beyond a simple implementation of web-based 3D virtual museum with different kind of artwork using a system designed for the museums and tested with pilot studies in museums such as the Kubo Gallery in San Sebastian.

2. SYSTEM DESCRIPTION

The application is focused on two different aspects: The part where the curator is responsible for the management and the part where the visitor just enjoys.

2.1 System Background, curator vision

Museums curators' work is very diverse. It consist of making the selection of an artwork to compose an exhibition, managing the space available to display these works, choosing where each work will be exposed, calculating the route each visitor will take and many other things. With 3DPublish, a museum curator will be able to do all this tasks from a single web interface solution based on tabs. It is designed in such a way to make all processes simple and intuitive, with the aim of allowing the curators' to work more dynamically and easier to create a virtual exhibition. It also allows the easier access for the public and for all potential visitors worldwide.

With the first tab museum curators´ find the artwork. Through various web forms they will be able to register, modify and delete artwork very easily. A work of art is composed of different metadata: title, author, year, technique, copyright, etc. and the most important, the administrator must upload a file to be linked to all this data. This file may be an image, video, presentation, or even a PDF document. The artworks could belong to a real exhibition or not, so curators will be able to create exhibitions with existing digitized real artworks, with just digital files or with a mix of the two types. The following image shows a new artwork registration form, within the upper tabs

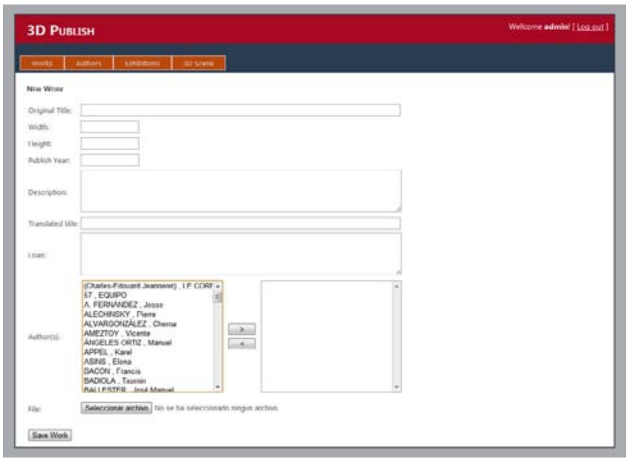

Figure 1: New artwork creation form

The second tab contains the artists´ management, offering the possibility of registering a new artist, modify or delete it. The metadata associated with an artist is data about his name, date of birth, life, etc.

With a third tab is the scenario tool. From here, the museum curators will be able to choose what works, which were previously registered, will be introduced in an exhibition. They can also manage exhibition space by creating new walls and moving them to find the perfect distribution. At the beginning the museum curator will always see an empty scenario for creating a new exhibition, but also old exhibitions can be loaded dynamically into the empty scenario if the museum curator wants to change anything. Museum curator will be able to save and load as many exhibition distributions as he wants. This feature is very useful for testing real exhibitions distribution before building them in the real life. The following image shows an empty scenario with 2 new walls and a work of art already in place.

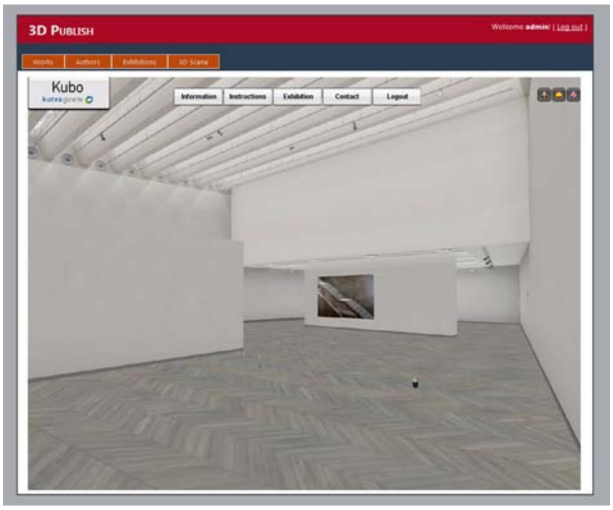

Figure 2: Creating new exhibition in an empty scenario

Finally the last tab is for managing exhibitions. Once the artworks and their authors have registered, and the distribution of the exhibition across the scenario is chosen, the museum curator can customize the exhibition by giving an informative description, a logo, creating defined paths through the exhibition, assign audio tracks to works as an audio guide or even storytelling, etc. From this tab, museum curator will also be able to choose which exhibition display for visitors by default and which ones will be public to be chosen by them. As always all through a web interface.

Thus, as we have explained, all the functions museum curator does every day are provided, and the creation of virtual exhibitions web becomes an easy and centralized process.

2.2 System Front end, visitor vision

Once the museum curator has published an exhibition, visitors can enter and enjoy it through internet. Entering museum virtual exhibition URL the visitor will see by default the empty scenario and it will load automatically the exhibition (data and associated artwork) which museum curator has marked as default. Once the content is downloaded the visitor can begin to walk through the virtual visit.

Visitors have several options to enjoy their visit. First they can see the exhibition information (subject, biography, etc...) And then they will be able to visit the exhibition through the virtual 3D scenario. The visitor could be a technological experienced user or not, and it is known navigation aids that are appropriate for experienced users may actually not provide a suitable level of support for inexperienced users and solutions that may improve the navigation performance of inexperienced users may not benefit experienced users beyond a certain degree (Walczak, 2007). Because of this, 3DPublish will allow visitors to visit exhibitions freely through all 3D scenario (instructions to move around the scenario will be displayed) or to do it through guided static paths defined by the museum curator. In both options, as showed in the picture below, each part of the exhibition displays information describing the work and its author.

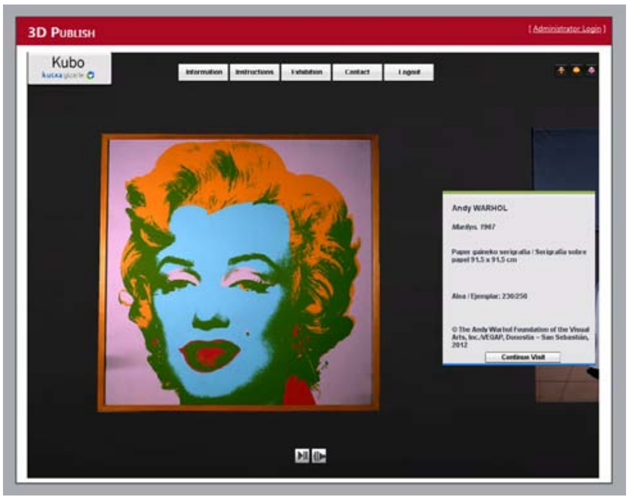

Figure 3: Visitor’s view for artwork data

Each work may also have assigned an audio track, to complement the information provided on the screen, and can be used by the museum curator to create a story that describes the exhibition context and make the exhibition more interesting and educational, for instance, to students. Digital storytelling can help them to understand complex ideas, and introduce new contents (Yuksel, n.d.).

Another option is that visitors will be able to change museum exhibitions dynamically. This implies reloading the empty scenario and loading another exhibition with its works and corresponding distribution. So the user may have a complete historical view of the exhibitions hosted at the museum he is virtually visiting.

3. SYSTEM ARCHITECTURE

In this section the set of tools chosen to develop the project will be described. It is a technical explanation focused on the museum curator’s part since the visitor portion is only the interface that displays all the processes of the server. Figure 4 illustrates the general layout of the 3DPublish application. Application core will reside in the web server and it has been programed in C#. Features associated with 3D scenario representation have been programed with JavaScript. The interactions between the different actors have been developed using REST services.

3.1 Content Management

The first feature 3DPublish offers is a content management system through a series of web forms. The file types this content manager supports were chosen because they are the most commonly used. For images, JPEG and PNG formats have been chosen, for video AVI format, for presentation PPT format and PDF format for documents. The museum curator may examine from 3DPublish web management any file of these formats that are on his computer and upload them to the web server. Once the file has been uploaded successfully, it is launched internally a conversion process to transform the source file to the final work which will finally be exposed in the exhibition.
For instance, AVI files will be transformed to OGG format (Waggoner, 2010) using ffmpeg2theora converser libraries. PDF files will have his data extracted (Wootton, 2007) into series of PNG images using Ghostscript libraries. And finally PPT files will be also transformed in a series of PNG files using Microsoft Office Microsoft.Office.Interop.PowerPoint libraries.
The first 2 libraries are free and are compiled into separate files for use in any situation, but the libraries to transforming a PPT file need an office installation to be used. So the web server must have Microsoft Office installed with at least PowerPoint package, which means that the server will run a Windows OS. Finally the developers decided to use a Windows Server 2008, and the 3DPublish application will be accessible and runnable through IIS. Once the files have been processed correctly, they were placed in a Content server, which may be the same machine as the Web server.
Other data associated with a work of art and the author (including the reference to the file path transformed) will be stored in a database server. In this case it was decided to set up a MySQL server to store data.

3.2 Spatial Management

Once the files have been uploaded and processed, and are available in the content server, and authors and their works have been registered in the database server, the museum curator will be able to start building the virtual exhibition. He will start with an empty virtual scenario (real or imaginary) that has been previously decided and it will be displayed through the Unity 3D free engine. Inside 3D scenario museum curator will have different works (which have been previously registered), a selector for picking one by one and placing them in the different walls of the scenario. He will also be able to use a simple tool for creating new walls in empty spaces of the scenario.

Once the museum curator has finished creating the exhibition, he will be able to save the 3D scene. Internally this means that all new elements (artwork and walls) included on the empty scenario will be recorded in an XML file. There will be an XML file in the content server kept for each exhibition. It will also be created a new database record for this exhibition which will keep the creation date of the exhibition, a meaningful name and reference to corresponding XML content server.

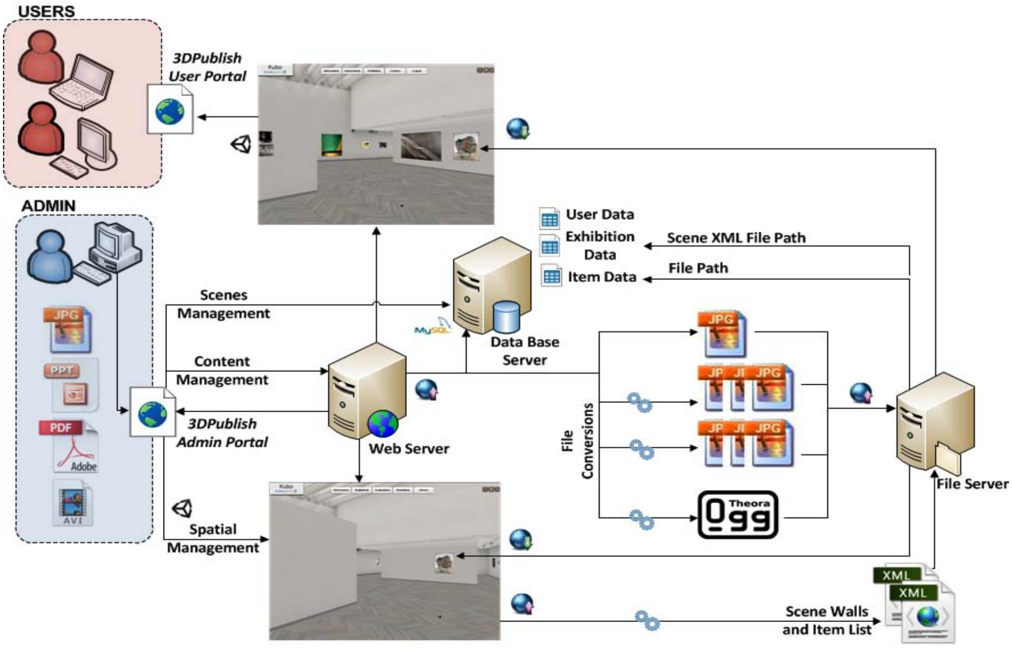

Figure 4: 3DPublish Architecture Diagram

The following figure shows the previously Figure 2 but with exhibition already finished.

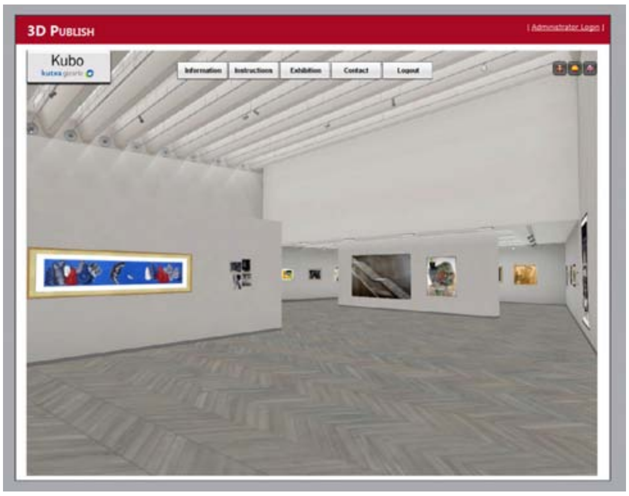

Figure 5: Exhibition complete vision

3.3 Exhibit Management

When the museum curator has finished defining the exhibition he will then be able to begin the creation of added value, for instance assigning a logo and a description to the exhibition for visitors. This process implies updating the exhibition record within the database. For creating guided routes or associate audio to the artwork it is necessary to represent the tree of the XML exhibition file in a web form context. But thanks to this feature the museum curator will improve the exhibition defining a complete audio guide by assigning audio to every piece of the exhibition or even, as already related above, using these audio tracks for creating a storytelling context. Finally museum creator will be able to create guided tours through the exhibition by choosing an order for works. All these features will be available as usual through web forms, with just two restrictions: the logo should be a PNG or PNG file, and the audio should be an OGG file.

On the other hand museum curator will be able to manage saved exhibitions, and for instance defining which the default exhibition for the visitor is, or selecting which saved exhibitions are public and because of this, ready to be chosen for being loaded in the scenario. Previously saved exhibitions could be deleted or remain unpublished too.

4. CASE STUDY OF THE KUBO GALLERY

As related above, 3DPublish tool born from Tourspheres project. In this project, the challenge was to reach a more valuable tourist behavior comprehension, so the visitor experience in a real museum space had to be complemented with the experience in a virtual space.

As responsible for creating this virtual space we realized that the museum curator usual processes for creating an exhibition in a real museum could be standardized and simplified for building virtual exhibitions in a flexible and intuitive way. And so, with the essence of a 3D game engine but simplified and oriented to creating virtual exhibitions flexibly, born 3DPublish. And, of course, the first exhibition that was created using 3DPublish was the virtual exhibition of the Kubo Gallery, a collection of artwork accessible from the museum website (Kubo Gallery Website, n.d.).

All the images of the virtual exhibition showed in this paper are the result of this collaboration included the following Figure 6 which shows the final result.

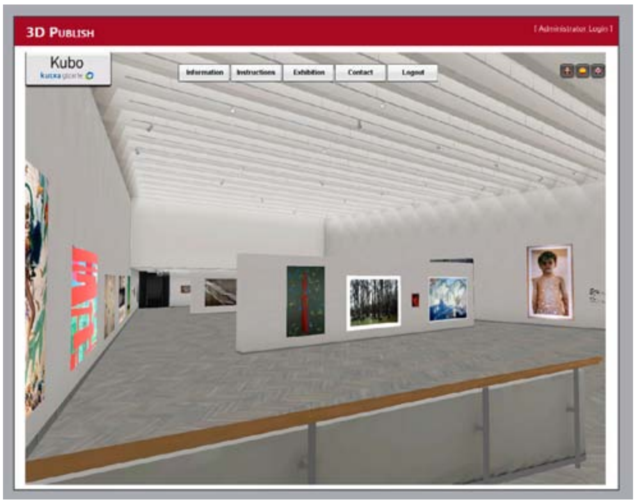

Figure 6: Kubo Gallery final result

5. CONCLUSIONS AND FUTURE WORK

We have presented in this paper a complete overview of the 3DPublish application. During the research process the developers found a gap in the virtual museum curator's daily work and because of this we have created this web-based application, with the ultimate goal of improving the processes of creation and museum maintenance of 3D virtual exhibitions.
3DPublish is the most complete option for creating virtual exhibitions based on a virtual (real or imaginary) empty scenario to make available final exhibitions for visitors, all through a centralized Web management processes oriented to the museum curatorial work.

From the work so far accomplished on this project, some new ideas for future development have emerged, to extend functions or improve the application. In the first place it would be beneficial to be able to work with additional image and video file formats. In addition to this, one of the more interesting improvements would be to allow 3D file processing in a streaming mode like the others file which represent artworks. Finally, to create a completely independent tool it would be ideal to be able choose a 3D complete virtual scenario for loading it in streaming mode in order to not rely on initial predefined scenarios to be put in the application compilation process. This means the scenario would be one more element in the content management of the application.
All processes involving the customization of the scenario elements will be also a great breakthrough. For example changing the color of a wall or his texture, move the lights position, etc. and all of these features, as always, on runtime through the website.
Many museums already have a content manager tool (online or offline) for their collections, such as The Museum Systems' TMS tool (The Museum System, n.d.), so it would be great to create an interface to use these collections or at least the metadata associated. In addition to this, it could be an important feature creating another interface for using Europeana public content.

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MEDIEVAL GRAVE FRESCOES IN THE SOUTHERN NETHERLANDS AND BRUGGE

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KEYWORDS: Medieval, frescoes, graves, Middelburg, Brugge, Aardenburg, Conservation, SCEZ, Raakvlak.

ABSTRACT:

Written to accompany a longer study, this short paper firstly highlights the uniqueness of medieval grave wall paintings in the south of The Netherlands and Brugge, Belgium; and secondly suggests mostly preventative conservation methods to aid the ongoing protection of these frescoes. Though graves are scattered, this study focuses on graves from three nearby but very different locations, Brugge, Aardenburg, and Middelburg. Graves share stylistic and motif similarities that result in the need for scholars to group these graves together as a type, in a way that was not done previously, as one by one the graves were accidentally found since the 1950s. Despite how these graves have been subjected to drastically different environments in previous decades, the problem of their conservation needs to be addressed using co-operation between the various regions rather than individually. The Saint Salvator Church in Brugge has already taken action recently, securing protection for the four painted graves with regulated air-conditioning under air-tight glass floor displays. The time is right to encourage appropriate action for other comparable graves nearby.

1. GRAVES IN BRUGGE, AARDENBURG AND MIDDELBURG

1.1 Introduction

Scattered over the south of The Netherlands and in Brugge, Belgium, are a number of medieval graves covered in wall frescoes. There is the odd grave in France and Germany, but otherwise these graves are unique to the region. Despite similar stylistic motifs and subject matter, until now they have rarely been considered as a group, and each local area handled itself independently. Fortunately many locations with graves are in Zeeland, putting them under the care of Stichting Cultureel Erfgoed Zeeland (SCEZ). To date, there are no known groups of graves with frescoes with which to compare those discussed in this paper. This paper encourages co-operation for the preservation of this local heritage to help with optimizing the methods of documentation and conservation. Each area has survived different environments which influence how they must be handled from here onwards. Firstly, a short description of medieval grave paintings is given, explaining what makes them unique. Then, an interpretation of the graves history and design brings them together as a group. Afterwards, an analysis of the graves condition will lead to a practical argument about how to stabilize and then treat and preserve these pieces of Dutch and Belgian heritage. This paper has been written at a critical time shortly after successful cleaning and display of grave frescoes in Brugge. The city was the epicentre of the grave origins, and today it could be the leading example of how to care for the rest of the graves in the surrounding region.

1.2 Medieval Grave Frescoes

Frescoed grave paintings are both unique and challenging to conserve, and there is a definitive lack of sources focusing on the unique problems they bring. It is crucial to distinguish how sources on general wall paintings or frescoes cannot necessarily be applied to grave paintings.

Graves do not hold the architectural significance of many wall paintings located on roofs or weight bearing walls. As a result, grave paintings are considerably more transportable and are often relocated. Often paintings will consist of mineral pigments painted over plaster and mortar, covering thin red brick walls. It is hard to assume styles of wall paintings coincide with graves, so dating is difficult. This is because graves are not meant to be seen, they are part of the medieval burial ritual. The dead needed to be buried within 48 hours of death leaving little time for painting to be completed (Information boards St Salvator Church, 2011). Interpretation of grave paintings must keep in mind their predominant role as part of medieval burial rituals. At their core, grave paintings, like general wall paintings share common physical threats of deterioration after excavation. They suffer from light, temperature, humidity, vandalism, poor prior treatments, flaking and so on. It is important to refer to literature on wall painting but with a close eye to ensure the appropriate circumstances are considered.

1.3 Historical Context

BRUGGE

Of all the cities that house grave frescoes, Brugge is the largest with 16 grave locations (Information boards St Salvator Church, 2011). It was likely the centre of this medieval practice due to its role in communication with surrounding areas. Further locations are known in Zeeland, Utrecht, South-Holland, North-Holland, North Brabant, Gelderland and a few in Germany and France. Almost nothing is known about how and why this practice spread to these regions. After excavations between February and May 2011, Brugge has the most recent information, and most effective display methods [Fig. 1].

Figure 1: Glass flooring in St Salvator Church, Brugge.

However, the graves were discovered during 1989-1993 excavations, approximately the same time Haakma studied the Aardenburg St Bavo Church grave paintings, published in 1994. Before recent excavations and display in Brugge's Sint Salvator Church, Haakma was the last to seriously study grave frescoes in the region.

The St Salvator church is filled with almost countless graves, but only four have frescoes. The four graves are permanently excavated, and are prepared for mass public viewing. The graves' walls are clean, often with a layer of new cement along the top of the walls for stability. The human remains are still under the layer of sand. They are still underground at their original depth, with a glass layer added above which can be walked on. Underneath the glass, light makes the graves visible. Results presented to the public via A0 posters in 2011/2012 in the church provided interesting interpretations of the grave fresco imagery. Due to the Franciscan influence the imagery is linked back to the name of the church. Christ is argued to be presented as the suffering Christ, and when with the globe, as *Salvator Mundi* - the blessing Christ [Fig. 2].

Figure 2: Blessed Christ, St Salvator Church, Brugge.

Mary is seen as the queen and mother or *advocate nostra* – the advocator and mediator in heaven who pleads the salvation of the dead [Fig. 3] (Information boards St Salvator Church, 2011). This is interesting, but only analyses the graves within the context of the church.

Figure 3: Throning Madonna with Child, St Salvator Church, Brugge.

In Brugge it is interesting that design motifs are not consistent. Angels will often be used as examples for this study because they are prevalent in all three locations. For example there is the pattern on long grave sides of depicting angels swinging incense burners, but in Brugge there are definite differences between graves. The first type is stiff, with heavy material clothes coloured in bands with black outlines. Wings are bold, with simple feather patterns created through the outline, and they are quite symmetrical. The second type is much less stiff looking. Bodies, arms and faces are twisted; along with the clothing they convey movement. The wings are far simpler. They are merely flowing black lines. Graves contain similar motifs such as small flowers, crosses, and a red repetitive border along the top. What is seen in Brugge is a consistency in topic, but not style. There is currently no certain explanation for this.

AARDENBURG

Through its proximity to Brugge, Aardenburg grew to be one of the biggest cities in Zeeuws-Vlaanderen. The St Bavo Church suffered extensive damage in October and November 1944 of the Second World War, which took a decade to repair (Hutsebaut, Dhont, and Aerts, 2010). It was during these repairs, that the first of twenty grave paintings were discovered on March 3rd 1948 by restaurator P. Postma. (Haakma, 1994). Since then, there have been additional excavations to explore the church's architectural history in 1952, 1955 and 1956 (Renaud, 1956; Devliegher, 1956). Restoration of the St Bavo Church was from 1947-1956 (Devliegher, 1956). The date the grave frescoes were painted is still debated. Dezutter agrees that the estimated date by Devlieger of approximately 1330 can be plausible (Dezutter, 1970). Although there have been other graves with paintings discovered in the immediate area, for example in Sluis, and Brugge, the Sint Bavo Church in Aardenburg contains the most, 20 complete graves, and two additional parts of other graves with medieval wall paintings. Today ten of the graves remain excavated, and have been lifted out of the ground, but are still above the same location. The rest have been filled in again after excavation and documentation were completed.

Art Historian and Archaeologist Dezutter completed an entire iconographical interpretation of every painting from 1969 to 1970 for his PhD. Although his descriptions were centred on Aardenburg, Dezutter included short introductions to other graves in Zeeuws-Vlaanderen indicating that he considered the painted graves of the region to be connected. Unfortunately the photo albums that accompanied his thesis are no longer to be found. However, the images by s 'Jacobs, show some characteristics that were also present in Brugge's Saint Salvador church (s 'Jacobs, 1955). Angels are often, but not always painted on the long sides of graves with varying degrees of similarity in the shape of the wings and halos. Smaller andreas crosses and larger lily crosses are painted, as well as plants containing the lily motif. Madonna and child, who is often throned, as well as Calvary scenes and the suffering cross are still common scenes for the short ends of the graves. However, there is no blessing Christ to be found. This is one feature that tied the Brugge interpretation to the name of the church itself. The painting style is variable much like those in Brugge.

MIDDELBURG

Middelburg is the capital city of the Province of Zeeland and the home of Stichting Cultureel Erfgoed Zeeland (SCEZ). The nine grave paintings in a crypt underneath the Abdijplein of Middelburg are crucially different from those in Brugge or Aardenburg because they have been relocated from their original burial place, and most have lost the context that comes with this. The paintings are presented as follows: one whole grave with four walls painted [Fig. 4], two short ends of a grave framed side by side [Fig. 5 & 6], and three long sides of unknown graves [Fig. 7].


Figure 4: Grave 2307-1 with glass casing, Middelburg.


Figure 5: Fragment 2307-2a without casing, Middelburg.


Figure 6: Grave fresco 2307-2b without casing, Middelburg.


Figure 7: Grave walls 2307-3,4&5, Middelburg

These paintings have recently received attention when SCEZ conducted a preliminary documentation of what condition they were in during April 2011. The documentation process was part of a larger study that included an attempt to trace the history of each painting, with some success. Two short ends of graves have been linked through literature and visual images to the 1947 excavation in Sluis.

Discounting the one inaccessible long side of a grave which faces the wall, visually the Middelburg graves are much more consistent in style than either Brugge or Aardenburg. Four visible long grave sides all contain angels swinging incense burners. There are aspects present in all three locations to some degree. For instance, colours are filled in without gradation, the shape being created by thick black outlines. Spaces are filled with large Andreas and Lily Crosses, and identical red borders along the top edge of graves. Motifs like the border, crosses, and small flowers are generally consistent at each location; it is the angels which change drastically in style in Brugge and Aardenburg. In Middelburg the flowers are less prevalent due to a generally fuller design, but they are also less shapely, those in Brugge having a six petal shape with a white center. Consistently as with Brugge and Aardenburg, the short grave ends in Middelburg share common themes. In this case the four short ends are made of two Madonna and Child depictions, one crucifixion and one Calvary scene. Once again there is no blessing Christ, this is so far found only in Brugge, giving weight to the interpretation that it is linked to the name of the church itself. It is indicated that Madonna and Child is a theme for almost every grave of this sort no matter the location, while the second end could have various options. After three comparisons it is evident that there are similarities and differences between the three locations. Most importantly however is the consistency of subject matter, painted onto the walls of graves built into the floor of large city churches in medieval times.

1.4 Conclusion

Aesthetic patterns and similarities link these graves together, but there is more they have in common. Behind the painted surface, the grave walls are primed with mortar and plaster on brick indicating the graves were prepared in a similar manner. As is the case with the Sintsalvatorkerk in Brugge, it is likely most others were also prepared hurriedly within 48 hours of the death. The Aardenburg graves are tentatively dated to 1330, and the others are even less certain. Nonetheless, although the 14th century was an unsettled one for the area, Aardenburg and Middelburg were never strangers with Brugge meaning they had constant contact with one another. Dezutter, the writer of the Aardenburg graves demonstrated in 1970 that the local grave paintings were associated with each other by describing them in his thesis, but unfortunately today the sites are still much more individual than they are a group.

It would be very beneficial for each grave site to embrace its place within this uniquely limited interregional phenomenon. Some change would be necessary. No longer would decisions be made considering only the immediate graves and surroundings in each city; local authorities from Middelburg, Aardenburg, Brugge and other minor locations would need to work with SCEZ and Raakvlak (Archaeology Service for Brugge and Ommeland) which would be challenging to implement. However, when these graves are treated together as a type much more can be achieved. Information can be exchanged, for example about display effectiveness, treatment results, deterioration, information found in one location. It is not the purpose of this paper to promote tourism but it must be acknowledged that it holds great potential. Brugge has already acknowledged the presence of visitor interest by putting up excavation posters and a visitor friendly viewing glass platform. Those in Middelburg rest only meters from the successful provincial Zeeuwse Museum, yet are not viewable to the public. Both Brugge and Middelburg are are popular tourist spots and Aardenburg is trying to build on its touristic potential. If the graves become well known the attention they bring would be positive, and might help to uncover some of the mysteries, not just of these big city painted graves but of those in smaller cities also. With so little information available about grave frescoes the initiative to work together to preserve and bring attention to these graves would be worthwhile.

2. CONSERVATION

2.1 Rationale

The first aim in recommended conservation will not be to immediately interfere with the painted surface, but to stabilise it. For this reason treatments must be done with caution, aiming to first stabilize, stop, or reverse the harm done by finding the root causes and how they are acting in each circumstance. Often deterioration is not isolated, with different causes potentiating each other (More, Mora and Philippot, 1984). The current state of each location will be commented on in order to explain why fragments require individual attentions and why the solution in Brugge, although hugely informative, will not necessarily suffice for all locations. Recommendations for stopping deterioration will be very basic, and price estimates do not include travel time, possible accommodation costs, or for unexpected delays or findings.

2.2 Brugge

Despite having so many graves in Brugge's Saint Salvator Church, the four medieval frescoed graves have been the ones exposed, researched and protected. Especially in comparison with the complete four-sided grave in Middelburg, the graves in Brugge appear to have extremely good cohesion between layers and little flaking. The walls are structurally sound, which is important since the graves are very close together and at times share the same walls, or walls that rely on one another for support. The environment beneath the glass is protected. There is a monitored air flow to stabilize the environment and monitor humidity and dampness levels, as well as light reaching the paintings. Being such a large and frequently visited church, it was also necessary to guard the paintings against the tourist visitations. The graves will be cleaned once a year, which is often. For some wall paintings cleaning only a few times in a century is recommended (Nisbeth, 1980). Therefore the frescoes in Brugge should be watched carefully for deterioration or rapid colour loss. The cost for yearly checks such as this would be at least €1300 annually. The cleanings in Brugge are one example of how different areas could co-operate to more effectively preserve the grave frescoes. Due to the similar material composition and age of the graves, if Aardenburg, Middelburg or other localities with such graves take into account how successful the repetitive cleaning process in Brugge is, it may save time, money, and help to find an appropriate method of preservation more quickly. For now, Brugge is an example to other locations.

2.3 Aardenburg

In Aardenburg, the twenty graves are difficult to comment on in terms of future conservation. Half of the graves are reburied, and the other half has been left exposed since the 1950s. Both these options can cause deterioration. In the case of the reburied graves, the deterioration will not be known unless an investigation is instigated. It would be tragic to unwittingly lose this heritage while it is out of sight and photographic documentation has been lost.

It is understood that the exposed graves have suffered discolouration from the church heating system and additional heating for concerts (Haakma, 1994). Photographic evidence from the 1950's has been lost so no direct comparison is possible. Excessive changes in heat, either higher or lower, are dangerous for paintings, even harsh seasonal weather can have too much sudden fluctuation in temperature. The heating system in Aardenburg was inefficient, and the gas heating released only a radiant heat and its soot was too easily absorbed into the bedacryl varnish that covered the painted layer (Haakma, 1994). Almost two decades ago in 1994, Haakma recommended that the first course of action for the Aardenburg frescoes should be to remove the discoloured bedacryl varnish that was added in the initial 1950's conservation. This advice is still yet to be acted upon. If action were to be taken today, a fresh research should be undertaken to measure aspects like discolouration, the relationship between the paint layer and the plaster, the danger of removing the varnish layer.

A large curtain was installed between the main body of the church where the graves are, and the apse where masses are held in an attempt to regulate heat change, but this is not enough. The graves have been raised above the ground so they are exposed from all sides rather than being surrounded by earth which is more consistent in temperature, but it is still possible to control the airflow to the graves. The best option would be to control the air flow of the entire church, since the room is used by worshippers to get to the front of the church for masses anyway. Geveke Technical Solutions in The Netherlands has estimated that an air-regulation fan (fan code: 90 4 SS L Enhanced BC VAV TB EC) would cost €11,000 to buy, €2,500 for installation and commission, and €1350 per year for maintenance. This is a very expensive undertaking, but will regulate the environment of the entire church. In this case, glass layers covering the tops of the graves need not be made air-tight, but must stop access to the grave space.

Although Aardenburg is a small, rather inaccessible town to visit, it is an important historical Roman city and the graves are a crucial aspect of the church and city's history. It is worthwhile investing in keeping the graves from deteriorating. Local academics have put much effort into establishing an interesting Archaeological Museum, historical city walks and more. Although the recommended changes are expensive, relocating the graves would not be advisable. Few other locations would be able to house ten graves. Starting a new investigation into the condition of these graves would cost approximately €6,500 with annual check-ups costing around €3,200 per year.

2.4 Middelburg

In Middelburg the condition of the painted surfaces is not consistent for all nine fragments, and a general conservation investigation needs to be completed for all. To begin with the first grave of four paintings: despite being protected by a glass layer the general condition of the painted surface is poor. There is much flaking, a large proportion of the surface is completely lost and has been filled with cement. There are large gaps where both mortar and plaster are missing showing a lack of cohesion between all layers, not just the paint and lower foundations, though this dominates. Air from the surrounding damp crypt has access to the grave via six small pipes along the long sides of the grave. However, this is not the original grave location; it is inaccessible to the public, and detrimental to the survival of the graves. As a result a new display area would be ideal. Investigation could be undertaken for them to be housed in other Middelburg locations such as the Provincial Museum, or another monumental building like the Nieuwe Kerk, both of which are popular visitor locations and only metres away from the Abdijplein crypt.

The second group of fragments is generally in much better condition than the first, although almost an entire half of one is lost. They are kept in an airtight display case which is fortunate due to the damp air in the larger room housing six of the fragments. There is evidence of past treatments, because of the shiny transparent surface. Damage can be seen in a spider's hole, a cracking in the more recent concrete casing, and salt blooming. Overall, the first painting, [Fig. 5] has much better cohesion between all painting layers, while [Fig. 6] is half lost, and with much flaking. Since these two frescoes are likely traceable to the Sluis St Peter's Church excavation, it could be a good idea to relocate the graves to the Sluis Museum that currently houses a number of frescoes from the same church excavation. Sluis is still part of the area monitored by SCEZ.

The third group of frescoes is unfortunately located in an empty corner of a passageway in the same crypt between the Abdij market entrance, and an elevator. It is subject to much foot-traffic, artificial lighting, dust, and they are grouped with a lot of other storage material. One wall is facing upwards, another has its painted surface half hidden behind the first as it faces into the room, and the third is completely facing the wall. Its pictorial content is to this day unknown. Considering dust, debris and paper had to be swept from the painted surface to allow for documentation, these also need urgent relocation. Without more information about their origins, a new location in Middelburg would be best. Including company commission, the initial treatments, checks and relocations of these graves would cost over €9,000 before adding necessary equipment, transportation machinery, or the cost of additional actions recommended during the Conservation analysis.

3. CONCLUSION

Each of these cities house medieval grave frescoes in different states of preservation, which are in need of different attentions. Despite these differences, visual similarities and common patterns in material use and building methods make them a unique product of the region's cultural heritage. There are still many questions that can better be answered by treating them as parts of a tradition. This paper has only supplied preventative means of conservation rather than methods that interfere with the painted surface, but stabilization is most necessary and this alone will cost over €30,000 plus the cost of yearly check-ups in all three locations. The purpose of this paper was to highlight the unique situation in small regions of The Netherlands and Belgium, in the hope that it will contribute to additional interest and research. In the meantime, the conservation recommended will aid the stabilization of the painted surface through a stabilization of the surrounding area. The main concerns being airflow, air quality, temperature change, light, and surface protection. From here onwards, there should be co-operation to help the survival of all these graves. Each city location requires a unique strategic effort for stabilization and preservation. Communication between cities will help to create consistency where possible by using the experiences of others to aid decision making in the future. In Brugge action has just been taken with the help of Raakvlak the local Archaeology Services. Aardenburg, Middelburg and other locations must encourage SCEZ and Dutch Archaeology Services that now is the time to copy and learn and preserve these cultural treasures.

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CLEANING PICTORIAL HERITAGE: MANAGEMENT AND DISSEMINATION OF CLEANING RECORDS AND STRATIGRAPHIC DATA

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KEY WORDS: Cleaning, painting, documentation, archaeology, stratigraphy, database, stratigraphic unit, solubility test, matrix

ABSTRACT:

At present, the process of documentation can be considered the cornerstone of the different tasks within the field of conservation and restoration of cultural heritage. However, this is not the case with cleaning. Despite its importance in the conservation of pictorial heritage, little effort has been made to improve the management and dissemination of information. Cleaning is one of the most usual procedures, yet, at the same time, it is also one of the most problematic and controversial. Therefore, it would be very useful that the information generated by cleaning could be widely disseminated and serve as reference for researchers and conservators around the world. When a conservator carries out a cleaning operation on a painting, two kinds of interrelated data are produced: stratigraphic data and cleaning records. Stratigraphic data are those concerning the configuration and composition of the stratigraphic structure on which the cleaning is carried out. Cleaning records gather together data concerning the actual cleaning process. All this information is key for conservators when working on other paintings. The information published is usually insufficient to understand how the intervention was carried out, so there is a need for standardized systems which allow a great deal of information to be gathered and disseminated with ease. This paper explains a selection of proposals, some of which are already in use, and others which are being developed: stratigraphic unit recording sheets, solubility test recording sheets and stratigraphic diagrams.

1. INTRODUCTION

Nowadays, at a time when important changes are influencing the field of conservation and restoration of cultural heritage, a number of questions must be posed concerning how to continue working in order to conserve pictorial heritage. One of these questions is: How can the way conservators work on cleaning, a complex and controversial procedure, be improved?

Innovation in this field has been evolving in the last decades through the development of new cleaning systems. In fact, any other line of work has been eclipsed by the impressive advances achieved by researchers such as Richard Wolbers (2000). Lack of interest towards other possibilities of innovation in cleaning, of attaining significant progress, has been enforced by the complete failure in trying to establish a "theory" of cleaning and subsequent attempts have all led to dead ends. Therefore, it is hardly surprising that researchers have clung to lines of work which, at least, allow progress towards a clear aim: designing new cleaning systems which permit work to be carried out in a more effective manner, while, at the same time, being safer for the work and the conservator.

The aim of this text is to show that there is another line of investigation which can also provide significant results in development and innovation within the field of cleaning pictorial heritage. The proposed line of investigation involves applying the work and documentation methodology used in archaeological stratigraphy. Although this methodology was developed in and for archaeological excavations, it can be applied to any kind of stratigraphic structures, including pictorial ones. Among the main advantages of this methodology when applied to cleaning are that it allows a greater amount of information to be generated, and also to develop solutions in order to attain a better dissemination of the data obtained.

Management and dissemination of information is a key matter in the innovation of cleaning, just as it is in any other field of investigation. The usefulness of the information lies in its reaching the largest possible number of researchers and conservators. So, in order to comply with this requirement, the use of different resources developed by archaeologists, such as stratigraphic unit recording sheets and stratigraphic diagrams, becomes of utmost importance.

2. ARCHAEOLOGICAL STRATIGRAPHY AND CLEANING

In the 1960s, archaeology started to evolve towards new techniques of excavation and documentation. The works of Barker (1977) and Harris (1989) put forward a more complete view of how an excavation should be carried out. On what principles was this archaeological methodology based? The basic principle was very simple: to decompose a structure into its essential elements, in such a way that the actions which had created it were revealed.

The essential elements are the stratigraphic units (SU), which can be positive (strata) or negative (losses). The units must be recorded as they are identified, starting with the more recent ones and working towards the older ones. This means that each layer is identified, studied and completely excavated before starting on the next one. Thus, the site's structure is "dismantled" in an inverse order to its creation. If the documentation obtained is sufficiently complete and rigorous, it is possible to "virtually" reconstruct the site with all its units, to understand the relationships among them and to establish absolute chronologies, or at least, relative ones (Roskams, 2001).

When these concepts are revised, the similarities between archaeological methodology and cleaning methodology become obvious. In the latter, a series of strata, which are studied and recorded, are also progressively removed (Figure 1).

Figure 1: Detail of a cleaning process. *Saint Anthony of Padua with Saint Anthony Abbot and Saint Nicholas of Tolentino*, anonymous artist (16th century), Convent of Santa Clara, Gandia.

Apart from general similarities, it is interesting to note that the tools used by archaeologists in the recording process can also be used by conservators. This has become more than obvious in the last decade, thanks to several papers. Watts *et al*. published in 2002 "The power of the matrix: the application of archaeological stratigraphy to the interpretation of complex paintings". The "matrix" is a flow diagram developed by the archaeologist Edward C. Harris in the 1970s, as a way of showing in a two-dimensional document the whole complexity of the interrelationships among units in an archaeological excavation. A few decades later, the "matrix" or stratigraphic diagram became an essential element in the stratigraphic study of an archaeological site, a building (Doglioni, 1997) or even an archaeological object (Vidale and Proença de Almeida, 2001). Figure 2 shows how the different units are organized in the diagram according to relative chronology (the oldest at the bottom and the more modern on top) and connected according to the relationships among them: for example, a direct connection by means of a line implies superposition (Barros García, 2004). The great advantage with this kind of diagram is that the information can be processed with different types of software programs, thus allowing multiple operations to be carried out.

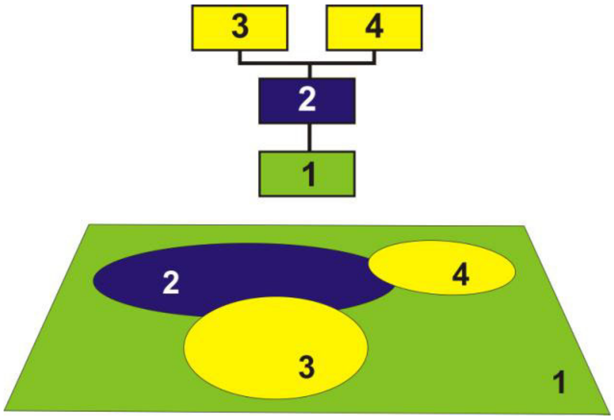


Figure 2: SU are organized in the diagram according to relative chronology and connected according to the relationships among them.

Prisco *et al.* (2004) have shown how the stratigraphic diagram can be applied to the study of the evolution of a wall painting. Shortly after, other works have developed the idea of applying archaeological methodology more specifically to cleaning, and indeed, using the SU recording sheet as the central element in the recording process (Barros García, 2009). In the recording sheet, all the information relevant to a stratigraphic unit is gathered together.

An "archaeological" orientation in the cleaning of paintings carries some noteworthy advantages concerning the possibility of innovation in the long term. It is a way of working which breaks with the aesthetic enslavement of the cleaning process while introducing a new paradigm: cleaning as a means of obtaining information, as an analytic process in itself. Firstly, it makes the conservator observe more rigorously the different strata and their relationships during the cleaning process and compels him towards a logical approach to complicated stratigraphic situations. Secondly, (and this is the aspect which will be dealt with here), it generates a great deal of extremely detailed information concerning the stratigraphic structure (made up of non-original strata) and the cleaning itself. Such detailed documentation, can in itself, be a very valuable resource with regard to research. One of the most interesting aspects is the creation of stratigraphic structure databases. This would permit, for example, comparative studies to be carried out between different restoration interventions.

A complete and comprehensive documentation allows a better analysis of the whole decision-making process in such a complex operation. Furthermore, as structures are compared before and after the intervention, it allows all the stratigraphic changes caused by the restoration process itself to be studied more accurately. In short, it means being able to expand the possibility of innovation, of advancing in a field of research in which there is still a great deal to do if we indeed aspire to attain something we can call, with propriety, "cleaning methodology".

3. CLEANING RECORDS AND STRATIGRAPHIC DATA

At present, the process of documentation can be considered the cornerstone of the different tasks within the field of conservation and restoration of cultural heritage. With the development of all kinds of software programs and the Internet, it is possible to create databases, to elaborate virtual reconstructions, etc.

Archaeology and architecture are two fields which are making the most of these resources with great success. Unfortunately, in the conservation of pictorial heritage, this is not so. The case of cleaning is a clear example. It is one of the most frequent procedures, while, at the same time, it is one of the most problematic and controversial. Therefore, it would be extremely useful if, during cleaning, a great amount of information could be generated which, in turn, could be widely disseminated and serve as reference for researchers and conservators around the world. When a conservator carries out a cleaning operation on a painting, two kinds of interrelated data are produced: stratigraphic data and cleaning records.

Stratigraphic data are those concerning the configuration and composition of the stratigraphic structure on which the cleaning is carried out. Some of that information can be obtained before the actual cleaning process is carried out, but some more information can also be obtained during cleaning. When a stratum is removed (for example, an overpaint) new strata, which were not visible before, may appear (for example, fillers or new overpaints).

Cleaning records gather together data regarding the actual process of cleaning, such as, among others, strata removed, solubility tests, cleaning techniques used and results obtained. This kind of information is relatively habitual (although it is not usually very complete) in specialized literature but it is practically impossible to find in the Internet. Despite the fact that these data are very useful for all conservators, there seems to be no particular interest in disseminating them. Insofar as stratigraphic information is concerned, this can be found more easily, but it tends to be limited to cross-sections.

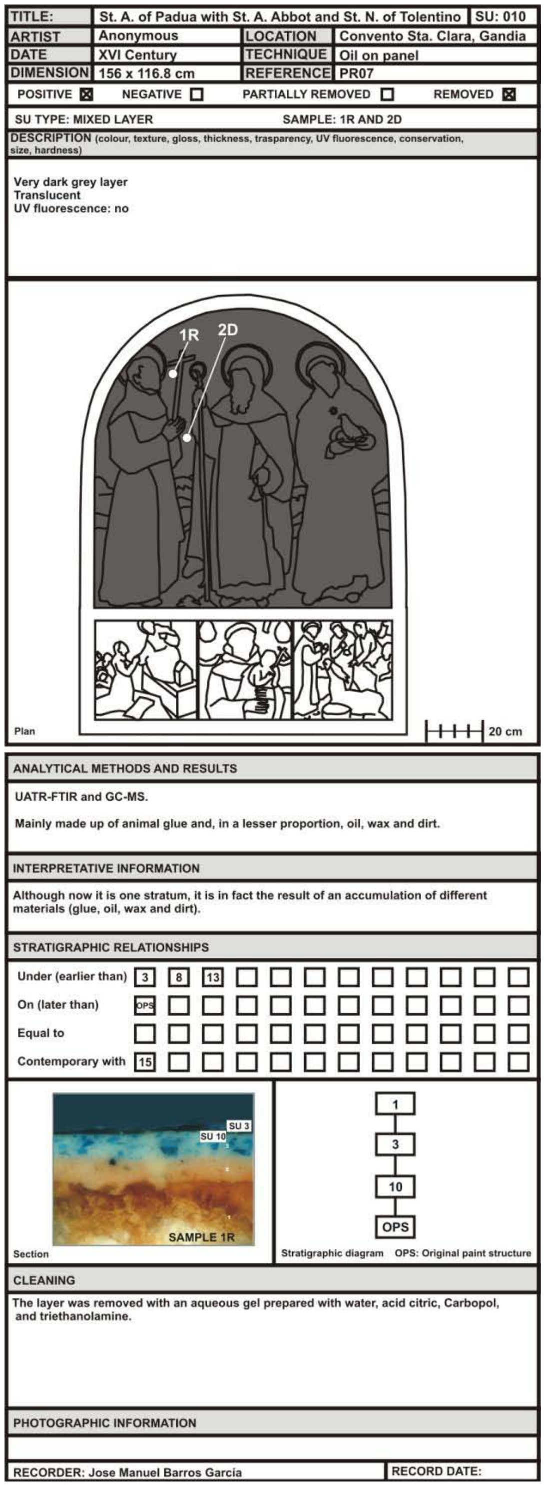
Cleaning is a process which is essentially concerned with subtle details: very thin strata which are hardly visible, numerous sensitive decisions made throughout the whole process, etc. All this information is fundamental for conservators when working on other paintings. The information which is usually published is just not enough in order to understand how the intervention was carried out, so there is a need for standardized systems which allow a great deal of information to be gathered more accurately and disseminated with ease.

The following sections explain a selection of proposals, some of which are already in use, and others which are being developed: SU recording sheets, solubility test recording sheets and stratigraphic diagrams.

4. STRATIGRAPHIC UNIT RECORDING SHEETS

During the cleaning process, each stratum (positive SU) and each loss (negative SU) is numbered and recorded separately on a SU recording sheet. Thus, data regarding their physical-chemical characteristics (colour, texture, hardness, composition, etc.), their location (situation on the horizontal level) and their relationships with the other units (situation in the stratigraphic sequence), are gathered together (Barros García, 2009).

Figure 3 shows both parts of this kind of sheet, adapted to document the cleaning process. This model has already been used, with very good results, in order to record the cleaning of several paintings (Barros García, 2009; Barros García and Pérez Marín, 2010). In addition to the SU's characteristics, the recording sheet also gathers some data concerning the cleaning, for example, how the stratum was removed. An important step in improving the recording system is to combine SU recording sheets with solubility test recording sheets.



TITLE: St. A. of Padua with St. A. Abbot and St. N. of Tolentino | SU: 010
ARTIST: Anonymous | LOCATION: Convento Sta. Clara, Gandia
DATE: XVI Century | TECHNIQUE: Oil on panel
DIMENSION: 156 x 116.8 cm | REFERENCE: PR07
POSITIVE ☒ NEGATIVE ☐ PARTIALLY REMOVED ☐ REMOVED ☒
SU TYPE: MIXED LAYER SAMPLE: 1R AND 2D
DESCRIPTION (colour, texture, gloss, thickness, trasparency, UV fluorescence, conservation, size, hardness)
Very dark grey layer
Translucent
UV fluorescence: no

ANALYTICAL METHODS AND RESULTS
UATR-FTIR and GC-MS.
Mainly made up of animal glue and, in a lesser proportion, oil, wax and dirt.

INTERPRETATIVE INFORMATION
Although now it is one stratum, it is in fact the result of an accumulation of different materials (glue, oil, wax and dirt).

STRATIGRAPHIC RELATIONSHIPS
Under (earlier than): 3, 8, 13
On (later than): OPS
Equal to:
Contemporary with: 15

CLEANING
The layer was removed with an aqueous gel prepared with water, acid citric, Carbopol, and triethanolamine.

PHOTOGRAPHIC INFORMATION

RECORDER: Jose Manuel Barros García | RECORD DATE:

Figure 3: SU recording sheet 10 of *Saint Anthony of Padua with Saint Anthony Abbot and Saint Nicholas of Tolentino*.

5. SOLUBLITY TEST RECORDING SHEETS

A clear example of the limitations inherent to the systems of documentation used at present in cleaning can be found in solubility test (ST) recording sheets. Solubility tests are usually carried out in order to study the solubility of the non-original strata, and can determine the success or failure of a cleaning process.

The different models of these recording sheets which have been published are all very limited in the information they can gather. Perhaps the most well-known is the one published by Masschelein-Kleiner in 1981, the use of which has been widespread, with some variations, in Spain. In general, recording sheets include, as basic information, the identification number of the cleaning test, the cleaning system used, the location (with a map to show the exact spot where the test was carried out) and the data obtained. Moreover, other data can also be included, such as the technique used to apply the solvent, the contact time needed to obtain a positive result, etc. A more recent example of a ST recording sheet is the one used in the application software *Modular Cleaning Program*, designed by Richard Wolbers and Chris Stavroudis (Stavroudis, 2009).

These sheets are not disseminated by conservators. However, given that it is extremely useful material for research purposes, its free dissemination on the Internet would be of great interest. The ideal solution would be the creation of databases which would include stratigraphic information (SU recording sheets) and cleaning test information.

An experimental, non-definitive database has been designed, to find out whether stratigraphic data and cleaning records can, in fact, be interrelated effectively. For this purpose, Microsoft Office Access 2007 was used, designing the simplest possible interface. From the program's main window, access can be gained to "Description of painting", "Stratigraphic study", "Solubility tests" and "Cleaning method" (Guillén Juan, 2009) (Figure 4).

The results of initial tests with this database have been very satisfactory, although it is necessary to achieve a much better relationship between cleaning record and stratigraphic data. There is a model which can be used to attain optimum results when designing this kind of databases: the software programs used by archaeologists to record SU and elaborate stratigraphic diagrams.

Figure 4. Database designed with Access 2007 to relate stratigraphic data with cleaning records.

6. STRATIGRAPHIC DIAGRAMS

Once the SU documentation is complete, all the relationships they participate in can be shown by means of a stratigraphic diagram or Harris Matrix. This diagram is, basically, a flow diagram which shows all the stratigraphic units and their relationships, whether they involve physical contact (superposition) or not. The units at the top of the diagram are the latest, the most recent, the ones found on the uppermost part of the stratigraphic structure. When one unit is connected to another one by a line, this shows that they are in physical contact (Figure 2).

However, not all relationships are as simple as those of superposition (Figure 5a). In order to record a stratigraphic structure such as that created by non-original deposits on the surface of a painting, we must resort to other relationships: ‘SU 1 and 2 are contemporary’ or ‘SU 1 and 2 are equal’. Two units are considered contemporary when they have been created at approximately the same time and are situated on the same stratigraphic level. In a stratigraphic diagram they are represented as units situated on the same horizontal level (Figure 5b). The relation ‘1 and 2 are equal’ refers to units, which originally formed part of a single unit, although now they have been broken up into various separate units (Figure 5c). This can occur when, for example, a layer of varnish has only partially been removed. This kind of relationship is shown by means of a pair of horizontal parallel lines connecting both units (Barros García, 2009).

The stratigraphic diagram permits all the SU, which could otherwise only be seen through a great many cross-sections, to be gathered together in one document. Furthermore, it also allows that information to be processed by means of different software programs. There are many programs, both free and otherwise, which despite having been designed for use with archaeological sites, can be used to record strata removed during cleaning. On the Internet, we can find several free programs together with some trial versions which allow a restricted use. Among the latter, *Harris Matrix Composer* (Traxler and Neubauer, 2008) is worth mentioning.

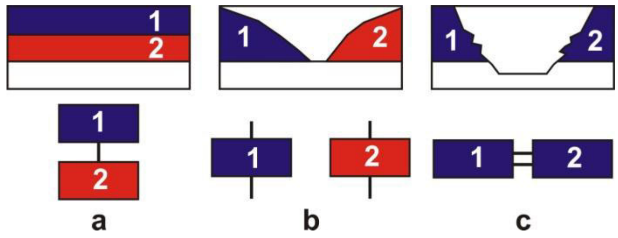


Figure 5. Relationships between two SU: superposition (a), 1 and 2 are contemporary (b); 1 and 2 are equal (c).

Among the free programs, ArchEd (Hundack et al., 2004) and Stratify (Herzog, 2010) are especially noteworthy, although there are also others available such as Tempo (Kähler Holst and Kähler Holst, 2004). The latter is different from the rest as it allows a great variety of relationships to be recorded. The SU recording sheets differ greatly from one software program to another. Stratigraf has a very complete recording sheet which offers the possibility of including graphic documentation (in several formats, such as jpg, bmp or gif). *ArchEd* and *Stratify* are free programs but their recording sheets are very basic (Figure 6). Nevertheless, these programs have been used to record the cleaning of several paintings with very good results.

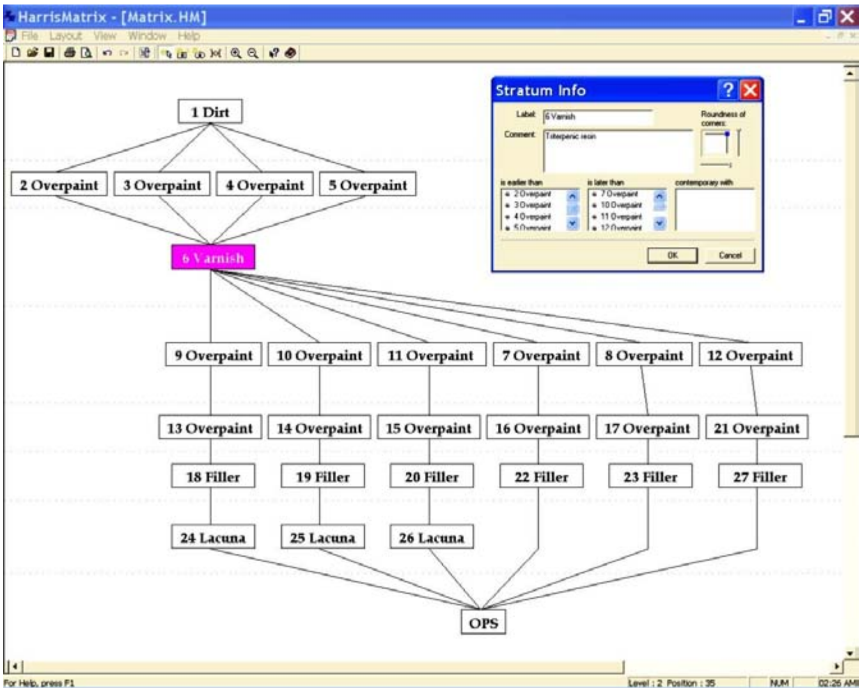


Figure 6. Stratigraphic diagram drawn with ArchEd.

7. FURTHER RESEARCH

Undoubtedly, all the ideas put forward in this paper require further development. The design of databases which integrate ST recording sheets with SU recording sheets is especially important. This would mean a great improvement in recording cleaning and a much better dissemination of the information. The connection between the two sheets is very important because it allows a cleaning test to be linked to the stratum on which it was carried out. A SU recording sheet records the description of the physical characteristics of a stratum (colour, texture, composition, etc.), its location on plan and its relationships with the other units (where the SU is situated within the stratigraphic sequence). This allows all available information concerning a single layer to be gathered together on just one recording sheet, which is why it is logical to link it to the documentation of the cleaning tests carried out on that same layer.

If, in addition, the stratigraphic diagram can be drawn with the same software program, the degree of documentation attained would be similar to that available to archaeologists working on sites. This would be an optimum situation for the proper development of research in the field of cleaning.

However, it is still necessary to take the previous step which consists in standardizing data. It would be necessary to have available a thesaurus, which does not exist yet, in order to accurately describe the SU, their characteristics and their relationships.

8. CONCLUSIONS

Archaeological stratigraphy can make a very significant contribution to establishing a methodological base for cleaning pictorial heritage and, in general, for cleaning any polychromed work. In order for this to occur, it is necessary to make a systematic use of the new systems of documentation, especially the SU recording sheets. This is particularly important when cleaning is carried out on works with very complex stratigraphic structures, with multiple non-original deposits from different periods.

There is a need for greater dissemination of the documentation pertinent to cleaning processes and stratigraphic data. The information published is usually insufficient to help develop research in the field of cleaning. Many museums only publish monographs which are not easy to obtain and, only too often, the information concerning cleaning is not sufficiently detailed.

From the design of databases which integrate SU and ST recording sheets, together with stratigraphic diagrams, it is possible to obtain a complete documentation of the cleaning process. From the use of these databases, it is also possible to achieve a very good dissemination of the information, which is essential nowadays in order to advance research.

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CULTURAL HERITAGE EDUCATION FOR INTERCULTURAL COMMUNICATION

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KEYWORDS craft traditions, craft education, cultural heritage, intercultural communication, European network, lifelong learning, trans-generational learning

ABSTRACT:

In this paper, cultural heritage is considered as an important aspect of intercultural communication and social cohesion, both in local communities as well as on the European level. In European societies of today, the role of the cultural heritage of arts and crafts is under discussion. Attention has turned to the importance of conserving and developing traditional knowledge and techniques. On the basis of this and the practical experiences from craft and cultural heritage projects in Finland and Cyprus, we briefly outline the project plan and its theoretical background. The main idea is to develop a European network of craft professionals and craft teachers who will develop and implement a series of training events and projects. Apart from supporting continuing professional development, the network will also initiate cooperation between artists, professionals and teachers. The aim is to create school and youth projects as well as cooperation between institutions in various countries in order to promote transnational projects. Occupation with traditional arts and crafts is not restricted to formal learning but expands to informal and lifelong learning activities. In this context, the transfer of trans-generational knowledge will be supported through community projects.

1. INTRODUCTION

1.1 Theoretical background

Throughout the ages, people have generated distinctive local cultures and the customs associated with them. These intricate relationships between people, the places in which they live, the ways they conduct their lives and the traditions and rituals that bind it all together, are all aspects of what is called 'cultural heritage'. (Kokko & Dillon 2010.) For centuries, knowledge and skills related to cultural heritage used to be an important aspect of peoples´ lives. The know-how related to local cultural heritage has been passed on from generation to generation, both in informal contexts, especially the home as well as in the formal educational contexts of schools. However, in today's postmodern world characterized by globalization, technology and the quest for economic growth, tradition in its many facets tends to be overlooked and sometimes even scorned as being a relic of older times. The manifestations of local culture in handicrafts, local history and customs are rejected by present day European societies; apparently having no accountable value, they appear to be unnecessary in the modern life-style. As a result, in most European countries the younger generation is out of touch with their countries' traditional culture, a part of their tangible and intangible cultural heritage. This alienation is strengthened by the economic cuts in education resulting in the subjects related to cultural heritage and arts being considered less important and dropped from the school curricula.

This development could be seen just as a normal consequence of changing times were it not for the growing realization that the loss of cultural heritage results in a loss of cultural identity and causes general impoverishment in many aspects of everyday life. Modern society needs to draw on resources and knowledge passed down from former generations in order to compete with the challenges of the 21st century, such as climate change, urbanization and migration.

1.2 Crafts as cultural heritage in the European context

Taking these factors into consideration, the persons presenting this paper have recognized an urgent need to preserve and transfer knowledge about cultural heritage to the younger generation. It would be necessary to see cultural heritage and sustainable development knowledge in this area as a shared resource for dialogue; this could promote, on the one hand, intercultural and intergenerational communication and thus increase social cohesion, while on the other, lifelong learning, youth entrepreneurship and creativity to ensure economic growth and sustainable development. Since the younger generation lacks the possibilities of learning about cultural heritage in their local communities and school, we have recognized that new ways of transferring this know-how are needed.

We are especially interested in particular aspects of cultural heritage which belong to ´crafts´ and ´craft traditions´. These forms of cultural heritage are manifestations of cultures and help in defining them (Lucie-Smith 1981). Craft traditions carry with them a long cultural heritage and knowledge which has been passed on from generation to generation. They include the skills needed to make artefacts and the lifestyles which have been associated with the expression of those skills. (Dormer 1997; Lucie-Smith 1981; Kokko & Dillon 2012.) Craft traditions can therefore be seen as "localised formulations of prescriptive knowledge". Information associated with cultural heritage is preserved in artefacts, tools, practices, modes of communication, lifestyles and in combinations of them all. (Kokko & Dillon 2010).

Eurydice, European Education, the Audiovisual and Culture Executive Agency, has produced an overview of the state of Arts and Cultural Education at School in 30 European countries. According to this report, "the role of arts education in forming the competences for young people for life in the 21st century, has been widely recognized at the European level. The European Commission proposed a European Agenda for Culture, which was endorsed by the Council of the European Union in 2007. This Agenda acknowledges the value of arts education in developing creativity. Furthermore, the EU strategic framework for European cooperation in education and training over the next decade, clearly emphasizes the importance of transversal key competences, including cultural awareness and creativity." (Eurydice 2009, 3.) "In 2005, the Council of Europe launched a Framework Convention on the value of cultural heritage for society (Council of Europe 2005), which identified the need for European countries to preserve cultural resources, promote cultural identity, respect diversity and encourage inter-cultural dialogue. Article 13 of the framework acknowledged the important position of cultural heritage within arts education but also recommended developing links between courses in different fields of study. In 2008 the Council published a White Paper on intercultural dialogue (Council of Europe 2008), which offered an intercultural approach to managing cultural diversity. This paper identified educational organizations (including museums, heritage sites, kindergartens and schools) as having the potential to support intercultural exchange, learning and dialogue through arts and cultural activities." (Eurydice 2009,7).

The Eurydice report shows that in two-thirds of the countries, crafts were represented in the curricula. However, the report showed a lot of variation in the curricula of different countries as well as the time allocated to craft education as a part of arts and cultural education. In all of the countries under study, music and visual arts were sectors of art education which were given greater value in the arts curricula.

For decades, UNESCO has paid attention to the importance of preserving World Cultural Heritage. The 1972 World Heritage Convention (UNESCO 1972) links together in a single document the concepts of nature conservation and the preservation of cultural properties. The *UNESCO Young People's World Heritage Education Programme* (WHE Programme) seeks to encourage and enable tomorrow's decision-makers to participate in heritage conservation and to respond to the continuing threats facing our heritage. Launched in 1994, the WHE Programme provides young people with the necessary knowledge, skills, network and commitment to become involved in heritage protection from local to global levels. New pedagogical approaches are developed to mobilize young people to participate actively in the promotion of World Heritage. (UNESCO 1994.)

2. EXAMPLES OF CULTURAL HERITAGE PROJECTS IN CYPRUS AND FINLAND

2.1. Traditional cultural projects in Cyprus

The "Anazitisi" Cultural Centre in Cyprus has initiated a series of youth projects about Cypriot traditional culture; these are mostly funded by the European Youth in Action and LLP programs. The aim of these projects has been to find ways of increasing interest about cultural tradition within the younger generation. Methodologically, this has been achieved by approaching the subject in informal learning situations using project-based teaching. Additional interest has been through the use of modern technology and web 2.0 -based applications. Cooperating with peers from other European countries and making visits for transnational activities, has further increased the attraction of these programs while at the same time supplying information about traditional culture in other countries.

In order to transfer knowledge about Cypriot traditional culture in other European countries, "Anazitisi" has also organized a series of Grundtvig programs. These programs started with the Grundtvig Workshop in 2010, which has been awarded an honorary distinction by the Cyprus LLP National Agency. It still continues today with the Grundtvig/ Comenius In-service Training program "Stitches and Threads- Traditional textile handicraft in Cyprus" which has been implemented five times during 2011 and 2012.

In the last two years (2010-2012) approximately 50 persons have participated in the youth programs and 60 in the LLP programs.Although interest in the program both inside and outside Cyprus is much more widespread, the only obstacle for the participation of more persons is the lack of economic resources. It must be noted that pre-registrations and expressions of interest for these LLP programs have reached the figure of approximately 300 persons in 2 years.

As a result of these programs, cooperation with several European institutions has been established. This has lead to participation in the Grundtvig Learning partnership "EU Treasure Hunt" which focuses on cultural heritage and the younger generation.

2.2. Experiences from an international craft course in Finland

During the courses author a) has arranged for international Erasmus exchange students and Finnish students as part of an International Study Programme for Education, the weak role crafts play in the curricula of various countries has become extremely visible. Before 2010, the name of this international course at the University of Joensuu was "Finnish Craft Education"; this gave information to international students about Finnish cultural heritage in crafts. Later on, along with the merge of the universities in 2010, this same course course was developed into "Cultural Heritage and Craft Education".

The objectives of this course (see UEF 2012, 14). are stated as being "after passing the course, the students will know the objectives and practices of Finnish Basic Craft Education and will become acquainted with some traditional crafts of Finland both practically and theoretically. The international group will learn to integrate cultural heritage education of crafts into the pedagogy of craft education; they will learn to look at the curriculum of art and craft education from a comparative point of view and to pay attention to the social, cultural, equality and gender aspects of art and craft curricula in Europe. Students will study the practical and theoretical basics of some chosen traditional crafts of Finland. The study unit consists of individual and group exercises concerning various aspects of crafts and craft education both in Finland and internationally. ICT is utilized in finding information about cultural heritage, curricula and the pedagogy of crafts." In addition, the students will visit a local craft centre. An important aspect of the course are the group discussions and essays the students write about the role of craft education in their respective countries' comprehensive school and teacher education course.

Essays and discussions have made it clear that crafts are almost non-existent in most European schools and generalist teacher education. Many young students participating on this course who are mainly future generalist teachers themselves, recognize the danger of losing their cultural heritage of crafts because crafts are also not practiced in most of their homes either. Some of them have learned crafts from their older relatives. (Kokko & Dillon 2010.) Finland and other Scandinavian countries are the only places where crafts are clearly represented in the curriculum of comprehensive schools as standard school subjects.

Up to now the Finnish craft curriculum has supported the traditional gendered division of crafts at school; most of the girls have studied textile crafts and most of the boys have studied technical crafts as wood and metal work. (Kokko 2009, 2011.) As a consequence, gender may have restricted the pupils´ involvement with various forms of crafts in Finland. This was not the case in most of the other countries represented in the course. When crafts were present in the curriculum, the content was the same for all pupils.

3. INITIATIVE FOR A EUROPEAN NETWORK ON CULTURAL HERITAGE AND CRAFT EDUCATION

Considering the role of arts and cultural heritage as a means for facilitating intercultural communication, we maintain that an increase in the importance of these subjects in school curricula and education in general, can function as a bridge to overcome problems caused by cultural diversity.

As is stated in the white paper on intercultural dialogue launched by the European Council (2008, 33): “Cultural activities can provide knowledge of diverse cultural expressions and so contribute to tolerance, mutual understanding and respect. Cultural creativity offers significant potential for enhancing the respect of others. The arts are also a playground for contradiction and symbolic confrontation, allowing individual expression, critical self-reflection and mediation. As such, they naturally cross borders, connect and speak directly to people’s emotions. Creative citizens, engaged in cultural activity, produce new spaces and potential for dialogue. (…) Europe’s cultural heritage can provide the backdrop to the plural European citizenship required in contemporary times.”

Since the problem can be identified in almost all European countries it is particularly important to establish means of cooperation between individuals and institutions in order to ensure the transfer of knowledge and good practice on the European level.

Based on this insight, from as many European countries as possible, we aim to initiate a European network which will bring together craft teachers, teacher trainers, artists, professionals in the field of crafts and other institutions, as well as decision makers involved in this field.

The first aim of this network will be to conduct research on the status quo of craft education in Europe today. On the basis of this research, we plan to develop in-service teacher training courses on a transnational basis leaning on the findings of Eurydice about the state of the professional development of arts teachers in Europe: "Continuing professional development (CPD) is a professional duty for teachers in the majority of European countries. However, the participation of arts teachers in CPD programmes is not regulated separately in most cases. Instead, general regulations on CPD usually apply to arts teachers as they do to all. As a result, there is little available information about the participation of arts teachers in CPD and their opportunities. Nonetheless, when such information exists, it shows that CPD for arts teachers receives little attention in many countries. Some of the national monitoring reports on the quality of arts education highlight the fact that arts teachers need to participate in good quality and appropriate in-service training. These reports, which exist in a dozen of countries, draw their conclusions from the results of standardised tests given to pupils, school inspections or surveys." (Eurydice 2009, 79.)

Apart from supporting continuing professional development, the network will also initiate cooperation between artists/ professionals and teachers, to create school and youth projects, also to promote cooperation between institutions in various countries for the creation of transnational projects. It is important that occupation with traditional arts and crafts is not restricted only to formal learning but will expand to become informal and lifelong learning activities. In this context the transfer of trans-generational knowledge will be supported through community projects bringing together members of the older and the younger generation and so support an increase in social cohesion.

4. CONCLUSIONS

In conclusion, we are of the opinion that enhancing the importance of craft education both in formal and in informal contexts will have positive results for the development of European society through supporting intercultural and trans-generational communication and understanding as well as youth entrepreneurship and creativity. Starting with cooperation between Finland and Cyprus and widening this cooperation to as many EU countries as possible, we aim to increase the importance of traditional skills and knowledge and show that their transfer into the 21st century will open new possibilities for sustainable growth and social cohesion.

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HERITAGE AND SUSTAINABLE DEVELOPMENT IN BEIRUT: A NEW ECOLOGY FOR THE CITY

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KEY WORDS: Heritage, Sustainable Development, Ecology, Ecocity, Beyrouth, ICT

ABSTRACT:

The objective of this reflection is to consider heritage as a model for sustainable development, whereby its appreciation contributes to the well-being of the city's citizens that we call Ecocity. The development challenges of Beirut, a city that is being reconstructed at an astounding speed after a civil war that modified a number of social values, highlights the objective: to create a link between heritage conservation, which considers the built environment and its functions, and sustainable development. In fragile urban environments such as Beirut, heritage must be considered as an inheritance to be at once preserved and encouraged to thrive. The city is at once a material and immaterial space which benefits from a global vision. The Ecocity is then the result of a balance, ever unstable, between the built environment and human requirements that alter over time. However this socio-economic evolution should not be considered in a negative light, as a healthy city is dependent on diversity and a respect for the balance between the built environment and its inhabitants. In fact, built heritage has always been diverse, however it has always found resolution by weaving together the lifestyles of its inhabitants with the local culture. These reflections have the capacity to pave the way for a reinterpretation of heritage conservation as a dynamic activity and viewing sustainable development as a contribution to growth of Ecocities.

1. INTRODUCTION

This paper presents the results of a multidisciplinary research project that combines the fields of architecture and the conservation of the built heritage, history, communications and computer science in the development of an Ecocity. In general, an Ecocity is an ecologically healthy city. In the particular context of our research it is associated with the idea of Green design that has been defined as Green as the means of allowing people to become more in touch with the environment in which they live. It takes into account natural landscapes and all the environmental effects. It is based out of creating buildings, which fit into their natural surrounds and give people a sense of place. Many of the key components of green design involve in-depth knowledge about a place. Knowledge of local environments is very important and Green buildings must account for sun intensities, temperature variation, precipitation and many other environmentally driven aspects. (R. Ludlow, 2007) Green design was an action naturally done by previous civilisations and our research project main objective is learning ecological insights and know-how from the previous generations. It is also about learning from the past by preserving its traces through a sustainability vision.

This study of new methods of experimentation will enable us to define and validate new orientations in the way we understand, structure and transfer acquired knowledge about a given architecturally significant complex leading to the development of an Ecocity. The aim of the project is to present the various experiences obtained during the interpretation of heritage spaces, using information and communication technologies. More specifically, it involves acquiring, through ICT, computer modelling and archaeologists' accurate documentation, an understanding of a sustainable vision established as the consequences of successive occupations of a historical city. It also seeks to gain a better understanding of the construction techniques and ecological know-how of the Ancients. The objective of this project is to introduce computer modelling, which is capable of showing the city's evolution over the centuries, in order to help us understand the city and how to move towards an Ecocity. This work will reflect on how to respond to certain challenges using the example of the experiences acquired at the site of the ancient city of Beirut in Lebanon. The Beirut project also helps to re-create and re-mould a city without having all the information and to test hypotheses that we would otherwise be unable to validate without compromising the heritage values of a site by physically reconstructing it. Such a compromise was experienced in the case of the district of Gemmayzé in Beirut which includes streets characterized by heritage buildings (Jidejian, 1993). (Figure 1)

Figure 1: One Building in the district of Gemmayzé

As a first step, we organized and described approaches for the transfer of knowledge that allowed us to exploit representations of spaces with the help of digital modelling software. We then developed the information structure necessary to validate strategies for defining an informative representation interface, using software applications that enabled us to create web-based interactive digital devices. Starting with the modelling of the street, we tried to identify buildings within this space by including text data and images. This itinerary proposes web content where the user can interact with the proposed interface and find out in real time where the heritage places are located depending on the action selected. This interface can display the various layers and forms of a place. So as to allow the user to learn through interaction with the digital modelling systems and by experiencing friendly interfaces (Zreik, 2005).

Our method aims to provide new solutions using technological means, with an emphasis on information gathered on a future ecocity. By using this approach, we hope to present a cognitive and interactive device which enables the users to identify sustainable architecture (Khayat, 2001). This system has the advantage of providing information on the site’s location, its shape and future threats in order to stimulate action leading to its protection and to how to transmit it to future generations.

On the basis of our research results, we propose an initial digital model. This model allows the user to clearly identify and communicate cultural heritage spaces and how important they are for the development of an Ecocity. Subsequently, a final computer model is proposed which would meet the user's target requirements more adequately. (Figure 2) The results we propose lead us to believe that we can rely on computer tools to communicate the importance of an Ecocity. Subsequent research contributes to the development of digital devices that can enable the communication of heritage spaces in the development of an Ecocity.

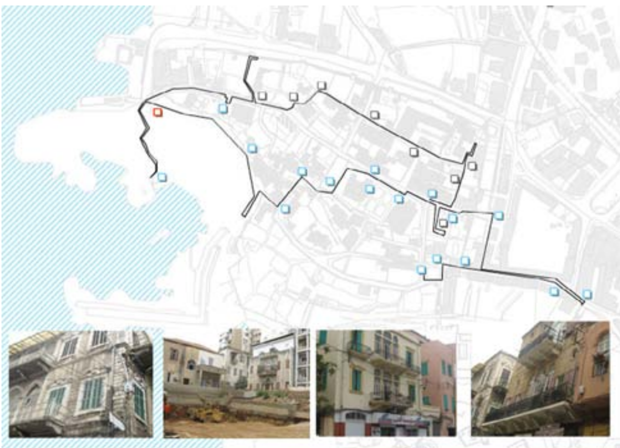

Figure 2: Itinerary tracing heritage buildings in the context of a future Ecocity : Beirut (El-Khoury, 2010)

2. BYBLOS ANOTHER ECOCITY

The idea of the Beirut project was inspired by another research project: the Byblos project at the University of Montreal (El-Khoury, 2008; De Paoli & all., 2007, El-Khoury 2010). (Figure 3) This research project also deals with the use of information and communication technologies (ICT) in the enhancement of architectural heritage as an example of sustainable architecture, particularly in the case of the Byblos site in Lebanon.

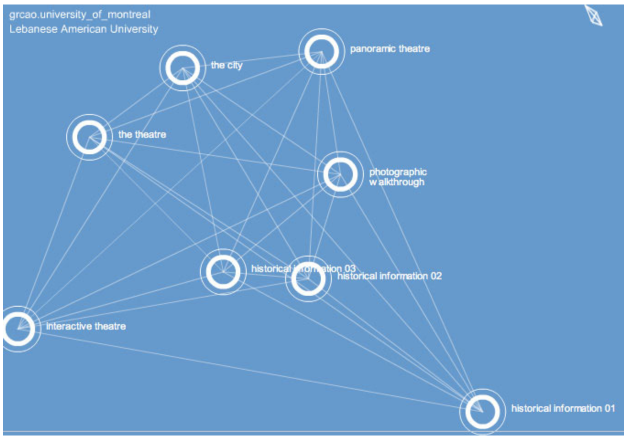

Figure 3: Byblos project at the University of Montreal (El-Khoury, 2008; De Paoli & all., 2007)

Located north of Beirut, the city of Byblos, which has been included on UNESCO’s World Heritage List since 1984, boasts a number of lively, ancient neighbourhoods, as well as an archaeological site where excavation work has unearthed a succession of abandoned cities revealing longvanished civilizations (Jidejian, 2004). “The chief attraction of Byblos for visitors is the superposition, in the same site, of ruins spanning 7,000 years of history.” (Dunand, 1973). Over the course of history, the site served as a quarry for successive civilizations. Such was the case with the Roman theatre, which was used as a source of stone by the Crusaders (1108) and whose origins date back to 218 A.D. Today, only the first five tiers and the stage remain. When it was first excavated, the theatre faced the setting sun. It was moved and rebuilt near the sea by archaeologists, and is now located at Early Bronze Age period levels. Some of his building'materials were used in the city and the castle. Tensile structures were originally positioned over dressed over the public spaces centuries ago. The purpose of such a structure was, according to archeologist Dunand (1930), to protect the audience from the heat of warm summers. In witness to this fact, holes that support these protective structures were found in the stones on the first steps of the theatre. Poet Lucretius likens the Velarium to a multicolored cloud that gives forth a crackeling noise, resembling fluttering pieces of paper, as it flaps. (Izenour, 1996) According to archaeologists, building materials' taken from the roman theatre of Byblos were used by successive civilisations as bases for their monuments.

The idea for this research (De Paoli, Bronson, Eaton, Bonnechère, 2005) arose from the study of certain ancient sites, of which sometimes only ruins remain, but that are important enough to merit further exploration: these ruins represent an example of sustainable architecture. There are multiple definitions of sustainable architecture, and this a subject of ongoing debate among the various disciplines involved in its development. In our case, we define it as the know-how arising from the construction methods and ways of life that characterize a place through a vision of sustainable development.

Sustainable development is a constantly evolving concept, particularly since 1987 when the World Commission on Environment and Development, sponsored by the United Nations conducted a study of the world’s resources after the international recognition of an impending and assured global disaster. According to the UN Brundtland Report, 1987, (Our Common Future): “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs ".

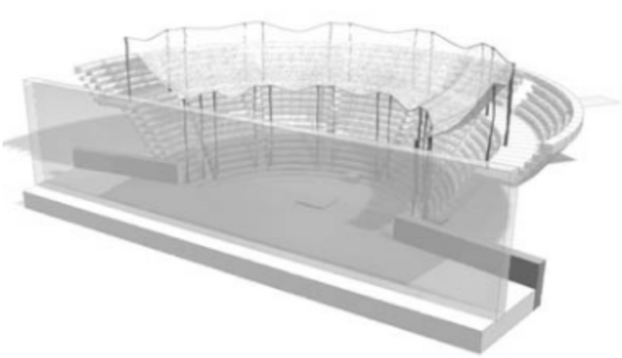

Figure 4. Roman theatre whose origins date back to 218 A.D.

The concept of sustainable architecture is increasingly gaining currency. The preoccupation with what we try to define as sustainable architecture may also contribute to a broader emotional basis of development practice, which can help us in the daily fight against the progressive world-wide destruction and decay of our environment. Sustainable architecture is not a static value, but an evolutionary concept. The notion of Sustainable architecture must not be fixed at a particular point in time – it is dynamic and evolves. Therefore it is important to look back in the past and learn from ancient civilizations and sustainable architecture.

These new approaches to sustainable architecture have guided our experimentation in developing new digital devices to understand Ancient environmental know-how through ICT. Old civilizations had the knowledge of local environments. They knew how to incorporate natural landscapes into the buildings design, which give people a better connection to the land. They also took into account creating monuments and buildings which fit into their natural surrounds and give people who use them a sense of place, as opposed to conventional architecture which pushes people away from the natural environment. Many of the key components of Ancient know-how involve in-depth knowledge about a place. They knew how to examine given conditions (site conditions, climate, daylight, and noise). Today sustainable architecture must account for intensities, temperature variation, precipitation and many other environmentally driven aspects. (R. Ludlow, 2007). In Byblos a sense of place is very present. Lessons from the past are great educational tools that will allow people to get a better understanding of sustainable architecture. Such lessons are a step in a sustainable future.

3. UNDERSTANDING SUSTAINABLE ARCHITECTURE THROUGH ICT

One of the main objectives of our research has been to gain an understanding of sustainable architecture in order to demonstrate how, using new methods of representation, we can attempt to virtually represent Ancient know-how, what is and what used to be. ICTs allow for an exploration involving the simultaneous use of simulation and experimentation. With regard to techniques of representation, it should be noted that in the twentieth century architecture was illustrated by means of drawings, plans, cross-sections and elevations produced by architects and archaeologists.

Three-dimensional reconstructions of spaces were often created as well. This is precisely what the archaeologist Maurice Dunand undertook during the excavation of Byblos in the 1930s. His sketch of the Roman theatre of Byblos is one example of this approach. It is prominently featured on a sign providing information about the architectural heritage to visitors (Figure 5). Graphic reconstitution in the form of drawings is still widely used today for the enhancement of architectural heritage. (De Paoli, El-Khoury, 2005a)

Figure 5: Sign providing information about the architectural heritage to visitors (Byblos site)

The restoration of ancient monuments is another way in which architectural heritage can be enhanced. Restoration, according to Pérouse de Montclos, involves a number of different areas. These include "consolidation", which is done to ensure a building's durability, without modifying it; "reassembly", the reconstruction of a building whose parts are still available on-site; "reconstitution", the collection and reassembly of authentic elements that have been dispersed; and "repair", the replacement of deteriorated parts with new, identical elements. (Gillot, 2006) The physical reconstitution of monuments is now regulated. The Venice Charter, which preceded the one adopted in Victoria Falls in 2003, states "that architectural heritage must be considered within the cultural context to which it belongs, that conservation and restoration of architectural heritage requires a multidisciplinary approach, and that the latter is not an end in itself but a means to an end, which is the building as a whole."

Finally, it should be recalled that, as with life-size reconstructions, scale models also are potential tools for enhancing architectural heritage. They can be used to depict a building, but often provide no information on the factors related to its construction history. Such models are limited to three-dimensional reconstitution of forms that are, in certain cases, hypothetical. They are often used as teaching aids, and also as tools to inform and entertain cultural tourists. (Gillot, 2006)
In this chronology of architectural expression, the use of computer models that allow for realistic simulations and realtime movement through virtual spaces, becomes relevant. Little by little, a physical environment is expressed through digital 3D spaces and a kind of architecture that is virtual and dematerialized sees the light and helps us better understand the construction of a building.

4. METHODOLOGICAL EXPERIMENTATION

In addition to the potential of simulation, virtual space opens new possibilities of expression and experience (Engeli, 2001). It also helps to re-create and remould a monumental complex without having all the information and to test hypotheses that we would otherwise be unable to validate without compromising the heritage values of a site by physically reconstructing it. (UNESCO, ICCROM, ICOMOS, 1994) This was the case of the Roman theatre of Byblos (A.D. 218), which we used as a case. study and which, as previously mentioned, was moved and rebuilt near the sea by archaeologist M. Dunand in the 1930s (Jidejian, 2004) In order to better understand the architectural heritage of Byblos' Roman theatre, a preliminary experiment was undertaken based on a multidisciplinary research strategy. This strategy allows the development of augmented reality experiences in order to make us feel present within old constructions as well as on the actual archaeological site. Based on the 3D models and photos taken from known positions on the site, we built 360° cylindrical panoramic photos related to specific coordinates. Then, through the different configurations of the building, several layers of the theatre were composed on the present site view.

The activity of comprehension and communication inside this dynamic virtual historical space is more intuitive and effective than using only abstract technical data for plans and orthogonal views. Furthermore, with ICT, we are able to remotely access these augmented realities. It will also be possible to experience them in an immersive way using projection systems, placing the participant directly in the past while respecting the user scale. In addition, sound effects may be added to enhance the sense of presence. This prototype can also be shared online within the researcher community. (De Paoli, 2005b, Khayat, 2006, El-Khoury, 2010) (Figure 6)

Figure 6: 3D models; corrected perspectives using QTVR.

Based on these research results, which draw their validity from the know-how of the architectural past, we are able to generate figurations of similar theatres: the researcher operates within a paradigm that brings together various types of solutions by means of "figurations". The use of parametric functions enables us to break down the construction process. The result is an approach that integrates various design process "operators" to enable the use of appropriately structured figurations that can be manipulated, transformed and organized into a figuration of the object. This process is somewhat similar to the reuse of architectural knowledge in the creation of an architectural work.

In designing a new project, architects use fragments of knowledge derived from ancient structures, whether these fragments are reutilized, or simply projected. The design is then based on the memory of a previous interpretation, since the extraction of reusable knowledge can be achieved through an interpretive process. (Leglise, 2000) It is with a view to reusing such knowledge that we take up and further explore this way of representing know-how in the case of the theatre of Byblos. It is important to note that our intention to transfer ancient know-how does not affect the situation of those researchers who are neither archaeologists nor tourism promoters, but who are attempting to understand the architectural heritage. Our goal is to propose methodological experiments to define and validate new orientations in the way we understand, structure and transfer the knowledge associated with a given site.

As a first step, we organized and described approaches for the transfer of knowledge that allow us to exploit representations of spaces with the help of digital modelling software (Figure 7).

Figure 7: Representations of spaces (analogical and digital)

We then developed the information structure necessary to validate strategies for defining an informative representation model, using software applications that enabled us to create web-based interactive digital devices. As shown in Figure 8, these experiments enable us to deepen our knowledge of the construction techniques and know-how of the Ancients, and to create computer models that illustrate the site's evolution over the centuries, to help us better understand the superposition of historic layers and suggest periods to which the research proposal might be applied. : the virtual reconstruction of the theater is linked with the site's evolution over time and connected to the urban development is visible in the real time animation achieved through this research project (http://www.arclab.umontreal.ca/BVM/)

Figure 8: Site's evolution: historical documents and digital representation (http://www.arclab.umontreal.ca/BVM/))

In order to develop modelling methods that take advantage of new information technologies, and to achieve our project's stated objective of designing computer-based approaches for representing the spaces that evoke the memory of a site, we generated an initial computer model of the theatre, in which the steps that have survived to the present (in darker colour) can be distinguished from the rest of the theatre as it might have appeared at the time. Based on this work, the reconstituted theatre was replaced in its original context, as it might have existed before it was taken apart and moved. The way in which these objectives were achieved will likely have a impact on the current work methods of the designers involved in the development of the Byblos site, as they can now benefit from the integration of information relating to the know-how of archaeologists, architects and historians to colligate a memory and propose new methodological orientations in the restoration of the man-made environment.

5. CONCLUSION

Through this work we explored different avenues to achieving the goals set forth in the research project. Our initial desire to understand sustainable architecture led us to delve further into the concept of architectural heritage and review previous work that had been done on the topic. This reflection process enabled us to define the themes for the Byblos research project by orienting its focus on the case of the Roman theatre. We realized that, although they are two different entities, the city of Beirut and the city of Byblos share a common concern: how to move towards an Ecocity. Experiments done through this research answered the main goal of this project.

We reflected on the types of solutions that could be brought to bear. Our conclusion is that research must not lead to the automatic generation of solutions. Rather, its aim is to provide a means of understanding spaces for the enhancement of local sustainable architectural heritage, using information and communication technologies. The reconstitution of a building facilitates not only the understanding of its ruins, but also the dialogue between professionals and nonexperts. The creation of 3D models provides a new opportunity for researchers and the public alike to better understand sustainable architecture. This work opens up perspectives for research that we will touch on briefly. These can be organized around two distinct poles.

The first relates to the future of architecture education, which is an essential function of a site such as Byblos if it is considered as a museum. From this standpoint, the question of how knowledge will be transmitted in the future is at the forefront, and researchers are asking themselves what type of museum should evolve in the years ahead. Will we see an "info-highway museum" in which data can be manipulated but not modified? Or a "museum without walls" that will be able to reach people wherever they are? (Allard, 1997). Heritage education is a key element in the creation of an open environment museum space, as in the case of Byblos, which opens onto the city. Knowledge is thus transferred in a kind of museum entertainment.

The second pole is the adoption of an interdisciplinary vision in the development of sustainability and outreach initiatives to better reflect the richness and subtlety of the content. Research perspectives are not limited to these two poles but extend to other areas as well. For instance, the results of this research project could be used for pedagogical purposes. Teaching sustainable architecture and design could be made more accessible by means of models to aid in our understanding of these sites.

It is in this direction that we continue our methodological experimentation; our aim is to contribute to the advancement of knowledge by integrating the expertise of the various disciplines involved in the enhancement of Ecocities, which can only be enriched as a result. ITCs become a unifying element between these different fields and thereby help to facilitate the process of shared decision making in environmental issues. "....we must at the outset take note of the countries and climates in which buildings are built." Vitruvius, Architect 110 B.C. (Stitt, 1999)

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CULTURAL EUROPEAN ROUTES: TRANSFER EXPERIENCES, SHARE SOLUTIONS (CERTESS)

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KEY WORDS: Cultural routes; Council of Europe; Best practices; Governance tools; Route plans; Cultural tourism.

ABSTRACT:

This paper deals with the building-up of a methodological framework on how to develop and manage Cultural Routes (CRs) by making use of route development best practices and governance instruments targeted to foster sustainable cultural tourism. CRs are intended by the Council of Europe as “historical lines interconnecting one or more regions and organized around topics whose historical, artistic or social interest proves to be European, either because of the geographical layout of the route, or due to its contents and significance”. Most ECRs lack comprehensive methodologies and governance instruments to implement effective strategies at regional level. The draft methodology is intended to be tested and detailed under a European project (CERTESS) where partners, while designing their CR Route Plans, will: a) adopt customised Best Practices; b) develop and adopt well-suited governance tools; c) promote local enterprises and products along their routes by use of innovative immaterial services including ITC. CERTESS partners intend to make their activities sustainable by integrating their Plans into a ECR strategy for establishing Europe as a "first cultural tourism destination in the world”.

1. INTRODUCTION

1.1 Council of Europe & EICR

1.1.1 Council of Europe. The Council of Europe (CoE), with its Cultural Routes Programme (CRP) launched in 1987, aims at demonstrating how the heritage of the different countries and cultures of Europe contributes to a shared cultural heritage, and intends to put into practice the fundamental CeO principles: human rights, cultural democracy, cultural diversity and identity, dialogue, mutual exchange and enrichment across boundaries and centuries.
In December 2010, the Committee of Ministers of the Council of Europe adopted Resolution CM/Res(2010)53 establishing an Enlarged Partial Agreement on Cultural Routes (EPACR) to enable closer co-operation between states particularly interested in the development of CR, while dictating the EPA rules for CR certification. Resolution CM/Res(2010)53 ruled on EPA statute and organs.
The EPACR seeks to reinforce the potential of CR for cultural co-operation, sustainable territorial development and social cohesion, with a particular focus on themes of symbolic importance for European unity, history, culture and values and the discovery of less well-known destinations.

1.1.2 EICR.

EUROPEAN INSTITUTE OF CULTURAL ROUTES

The European Institute of Cultural Routes (EICR) is a a non-profit association established in July 1997. Since 1998, EICR has been in charge of ensuring the continuity but also the development of the CoE’s CRP.

In the framework of EPACR, EICR acts as a technical body for operational purposes. Its role is to examine applications for new projects, to monitor activities in the field and co-ordinate the work of partner organisations and to disseminate and archive information documents.
EICR is therefore in contact with many countries, regions, municipalities, NGOs, European institutions, etc. and with many of them has established long-term cooperation.
In the past - after meetings, projects, seminars, workshops to analyze governance and funding rules - one of the main conclusions was that the regional level is an essential key for trans-border ECRs since the majority of ECRs networks are composed by regions, districts or clusters of municipalities, even if the route goes through several countries.
EICR prepared in the past a report for Congress of Local and Regional authorities (CPLRE of Council of Europe) reflected in the adopted resolution on ‘Cultural tourism, element of promotion of sustainable development at local and regional level’.

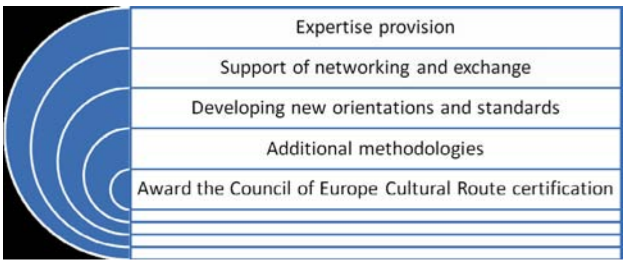

Figure 1. Policy-making and standard setting

1.1.3 Present constraints. To date 29 CoECRs have been certified. Most of the 29 certified CoECRs show:

- unclear definition of governance concept (integration of activities, management, coordination, etc.);

- too wide diversity of organizations involved in the CR governance (non-profit agencies, associations, foundations, etc.) and mostly SMEs;
- lack of common standards, programmes and quality control tools;
- lack of managerial and training models to facilitate sustainable and competitive development of the CRs;
- insufficient understanding of how a CR system works (what is the demand, how fragmented is the supply, etc.).

This leads to an insufficient economic exploitation of the routes and territories concerned, with a resulting limited contribution to territorial cohesion.

The identification of new CRs lacks guided access to well recognized ICT tools (e.g. GIS marking of routes) thus achieving non-homogeneous nor comparable results (f.i. route marking and signalling tend to vary from one route to another, sometimes causing misleading interpretations and consequent inconveniences to travellers).

There is also a limited evidence of good practice experiences readily accessible to CR actors. Previous experience reveal, furthermore, that identification and dissemination of good practices is often an uncrossed threshold to effectively transferring them to other regions by replication and adaptation.

The need of a concerted methodology for the whole process of CR development is therefore recognised as of priority.

1.2 CERTESS project

1.2.1 Standard reference methodology. CERTESS project stems from the necessity to develop a standard methodology for ECR development & certification by addressing the present context deficiencies towards a more coherent system of route identification, structuring, fruition and preservation.

1.2.2 Pre-project activities. Many regions attended the 2010 European Tourism Day, organized by the EC on the CR topic, and 3 other EU meetings were held on the same subject.

EICR & the Ministry of Culture of Luxembourg decided to propose to some of the participating regions to prepare an INTERREG IVC project, to identify critical issues and to find common solutions to be shared with other regions interested in implementing CRs.

Ad-hoc meetings were subsequently held:

- at the European Conference on the Via Francigena Route, in Rome (11 Feb 2011),
- at NECSTouR in Brussels on 23 Feb 2011,
- at the European Conference in Luxembourg of 28-29 March 2011 on the impact of cultural routes on SME's innovation and competitiveness, attended by representatives of CoE, the DG Enterprise and Industry of the EC, the European Parliament, the EICR, experts and coordinators of several CRs, etc.

CERTESS project partners were selected out of those who attended the said meetings & events and are all either involved in CR management or have expressed their interest to develop new CRs.

1.2.3 The INTERREG IVC 2011 call. CERTESS project proposal was formulated and submitted under Priority 2 and, in particular, the sub-theme "Cultural Heritage and Landscape" of the INTERREG IVC (2007-2013 Programme Period) 4th Call ended on 1st April 2011. The project was successfully selected for funding in December 2011 and started its operations in April 2012. Its completion is envisaged in November 2014.

1.2.4 Aims of CERTESS project. It has been agreed to have the regional level as a reference level for CRs promotion, in order to:

- help regions to cooperate better,
- have an exchange of experiences,
- share solutions,

with the aim to implementing CRs as an important element of European integration.

An interregional project is, in fact, one of the solutions to ensure regional exchange and agree on common definitions, standards, indicators, coaching and tutoring methods.

CERTESS project is deeply rooted in the past and ongoing involvement of project partners in promoting CRs and built on the well-placed EICR position as an overseeing agent of route recognition and promotion, aims at adding value to CRs and promoting them as part of a variegated and multi-content network in the whole Europe.

1.3 CERTESS partnership

CERTESS project is implemented by 12 partners from 10 EU Member Countries.

Partner	Location	Country
European Institute of Cultural Routes	Luxembourg	Luxembourg
Lazio Region	Rome	Italy
Dept of Local Government	La Valletta	Malta
Salzburg Research	Salzburg	Austria
Tourism Agency of the Balearic Islands (ATB)	Palma	Spain
Regional Ministry of Tourism, Commerce & Sport della Junta de Andalucia	Sevilla	Spain
Karlsruhe Institute of Technology	Karlsruhe	Germany
Zlin Region	Zlin	Czech Repub.
Admin.ve District of Gorlice	Gorlice	Poland
Ministry of Culture	Luxembourg	Luxembourg
Sibiu County Tourism Association	Sibiu	Romania
Jamk University of Applied Sciences	Jyvaskyla	Finland

Table 2. CERTESS project partners

2. METHODOLOGY

2.1 Objectives

2.1.1 General objectives. The methodology to be developed and tested under CERTESS project aims at establishing a European reference model procedure for:

- defining, structuring and promoting a sustainable CR, thus contributing to Europe 2020 tourist destination target;
- setting up shared tools for EU regions to improve their socio-economic setup and competitiveness while preserving the local cultural heritage;

- contributing to implementing the EPA-CR of the CoE.

2.1.2 Specific objectives*.* Specific objectives of methodology application to specific CR initiatives are here identified.

A. Knowledge-base Development. Creating a knowledge-base in the field of valorisation of cultural heritage and its socio-economic context, by identifying and documenting aspects of geo-historical evidence relative to a specific CR theme and its associated cultural heritage local assets.

B. Capacity Building. Building an CR-based capacity by: (i) by strengthening the guidance role of regional & local bodies as policy makers co-acting with stakeholders; (ii) reinforcing public-private cooperation; promoting local CR-related enterprises & products by enhancing their integration and quality level.

C. Sustainability. Contributing to ensure the economic and environmental sustainability of CR-related activities. Economic stakeholders along the route need to acquire a global understanding on how the route system works, what is their role to play and how to satisfy travellers` expectations, while also tackling the environmental issues deriving from CR fruition.

2.2 Methodology stages

The reference methodology is preliminarily outlined in this para. 2.2 and in Figure 3, with a special account paid to the Rules established in Resolution CM/Res(2010)52 and its Appendix. The conceptual structure is preliminarily organised in 6 Sections intended somehow also a sequence of CR development stages. CERTESS project shall experiment the application of most components and achieve evaluation results useful for the optimisation of the methodology, in view of a possible routine application in future.

2.2.1 CR theme development. Section 1 deals with the geo-historical and cultural background and character that lay behind and justify the theme proposed for a new CR. Themes are to be selected among the priority fields of action indicated in part II Appendix to Resolution CM/Res(2010)52, namely:
1. Co-operation in research and development
2. Enhancement of memory, history and European heritage
3. Cultural and educational exchanges for young Europeans
4. Contemporary cultural and artistic practice.

An important element is represented by the setting up of a common Glossary of terms and definitions relevant to CR establishment and development.
In general, each CR promoter shall:
(1.1) identify the theme of interest and ascertain the geographic transnational alignment in case of a physical CR or its reference area in case of a virtual CR;
(1.2) collect available historical-cultural documentation on the proposed CR theme;
(1.3) organise the theme reference contents into a specific web-based database.

2.2.2 CR network setup*.* Section 2 deal with the structuring of permanent relations, legal and operational, among all subjects involved or interested in the developing the selected CR both at transnational and at local regional level.

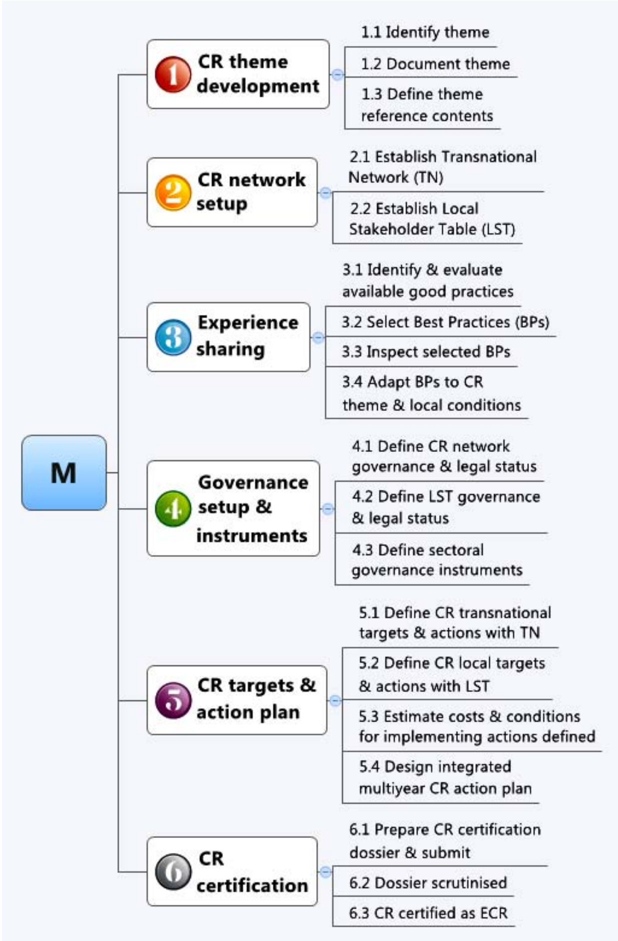

Figure 3. Methodology logical structure

In CERTESS each partner shall establish during project life a Local Stakeholder Table (LST) expected to:
- contribute to benchmarking the good practices identified by each partner at its local area level;
- recommend those good practices to be selected as Best Practices (BPs);
- organise local dissemination/evaluation seminars to identify suitable governance instruments;
- assist in designing the Route Implementation Plan (RIP);
- contribute to mobilize local socio-economic & financial resources to support the RIP implementation;
- cooperate in making project outputs sustainable in the medium-term.

The stake-holder analysis consists of a 4 step process:
1. identify key stakeholders;
2. assess stakeholders' interests and the potential impact of the CR initiative on those;
3. assess stakeholders' influence and importance;
4. outline each stakeholder's participation strategy.

Stakeholders are identified by utilising a power/interest matrix to map out local stake-holding members and classify them by power exerted over project-related decisions and by interest shown versus the CR initiative or a specific objective/topic.

Relevant partners will endeavour to promote after project completion a Transnational Network (TN) on the selected CR theme.

2.2.3 Experience sharing. Section 3 is the core of the methodology and the basis for final outputs. Relevant experiences are identified, analysed, reviewed, benchmarked so that resulting experiences of excellence are field-inspected, become subject for tutored transfer and eventually become the backbone of the actions to be planned.

In CERTESS the following is envisaged:

(3.1) Good practices are selected by cross-comparing similar experiences in different areas or implemented projects utilising a standard form with a related guideline and check-list to document the quality characteristics of the practice analysed.

(3.2) Practices of excellence (BPs) are preliminarily chosen among the previous ones.

(3.3) Site visits are made to partner regions to inspect BPs identified.

(3.4) Benchmarking sessions are held to confirm the chosen BPs and to select at least 1 BP for each thematic area for replication/adaptation. In addition, site tutoring sessions are performed in receiving partner regions by partners that have developed a specific BP among those selected. An expert team cooperates to transfer a specific BP by establishing a replication/adaption process to suit local conditions.

2.2.4 Governance instruments. Section 4 tackles only governance instruments that relate to the establishment/ development of a CR and to those activities/subjects represented in a TN or a LST.

In CERTESS local dissemination/evaluation seminars are organized by LSTs to:

(4.1) define CR network governance and legal status;

(4.2) define LST governance and legal status;

(4.3) define sector governance instruments to be applied for CR development.

2.2.5 CR targets & action plan. Section 5 concerns with the design of targets, strategies and actions suitable for establishing, developing and having certified a specific thematic CR selected by the promoting TN.

CR transnational targets and consequent actions to be implemented are defined at TN level.

In CERTESS the following is envisaged:

(5.1) CR local targets and consequent actions to be executed are agreed at LST level.

(5.2) Costs and conditions for implementing the defined actions are estimated.

(5.3) A Route Implementation Plan (RIP) is developed for each CR, thus setting the basis for a multiregional scheme of development activities regarding each CR network. Each RIP shall provide a concrete roadmap for CR enhancement in all participating regions by institutional engagement and stakeholders' involvement and shall consist of:

- networking-governance-sectoral actions to be executed,
- multiyear budget for action implementation,
- financing lines related to the RIP as a whole or to individual sectoral actions (cultural services, SMEs, etc.).

2.2.6 CR certification. In Section 6 steps are defined for the new CR post-establishment certification as ECR.

This eventual stage (not envisaged in CERTESS) is to be performed only once a specific new CR has been firmly established and important actions included in the RIP have been implemented. Once this is done, then the following steps follow:

(6.1) A CR certification dossier is compiled in compliance with CoE requirements and EICR directives.

(6.2) The CR dossier is then scrutinised by EICR. If important aspects are lacking, then the dossier is sent back for upgrading. If the dossier is satisfactory, then EICR recommends for the CR certification to Governing Board of the EPA in accordance with CM/Res(2010)52.

(6.3) The CR is certified as a CoECR.

2.3 Outputs and Results

2.3.1 Outputs. Main expected outputs are those indicated in italics hereunder. Those foreseen in CERTESS are indicated in quantitative terms are:

1. *CR theme development.* CR themes developed. Geographic and historical-cultural databases established.
2. *CR network setup.* CR Transnational Network defined; 11 Local Stakeholder Tables established.
3. *Experience sharing.* 30 good practices documented; 10 BPs selected; 4 site visits performed; 2 benchmarking sessions held, 4 site tutoring sessions held.
4. *Governance setup & instruments.* 11 local dissemination/ evaluation seminars; 80 governance instruments initially identified for 4 thematic areas; 11 policies finally earmarked.
5. *CR targets & action plans.* 11 Route Implementation Plans developed.

2.3.2 Results. Main expected direct results are:

1. CR theme development, with the associated result of an historical and cultural enriched awareness.

2. CR network setup, with the associated results and an increasing cooperation at interregional level in Europe.

3. Experience sharing, based on the joint recognition and exchange of consolidated practices in CR development.

4. Governance setup & instruments, capable to meet concrete needs or contribute to remove obstacles or critical issues as identified.

5. CR targets & action plans. strengthening of project planning capacities in the perspective of a sustainable development at inter-sector level. The plan, thus, represents a concrete roadmap for the CR enhancement.

6. CR certification. An overall result is the strengthening of cooperation between EICR & EU regions through the shared adoption of standardised methodology, procedures, contents and multi-sector action models.

CERTESS envisages results primarily related to point 3, 4 and 5 above.

3. CONCLUSIONS

3.1 Innovative and Original Character

The above methodology, applied in CERTESS, shows an innovative character and approach, as it tackles in a co-participatory manner the issue of cultural route in relation to economic promotion of territories intersected by physical itineraries.

No efforts are evident of on-going initiatives aimed at streamlining policy matters to include promotion of cultural routes at regional or sub-regional level. In other words, a clear gap is evident between declarations at national and transnational level, as well as European level, and regional approach and implementation policies relevant to a number of specific themes or topics such as assurance of quality services and their continuous improvement as well as material and immaterial

enhancement of routes including landscape and environment in special way as essential components of the route.
Development of Route Implementation Plans for the governance of cultural routes is CERTESS's most innovative aspect. The project aims to identify and tackle by a strategic format some of the main topics of cultural heritage governance, namely: (a) setting or expanding a cultural route, (b) providing necessary infrastructure support (material and immaterial), (c) ensuring quality and safety standard for their fruition. The project thus increases the competitiveness and sustainability of the cultural tourism in EU territories intersected by cultural routes and their territorial cohesion through several integrated action tools.

3.2 Impact and added values

CERTESS acknowledges the INTERREG IVC Programme emphasis on the importance to distinguish between practice transfers and policy impacts.
Transfer of practices constitutes only one aspect of the benefits of interregional cooperation having European relevance and value, whereas exchange and transfer of experience can also lead to more **structural changes** within the regions. Such structural changes are deemed to be part of the Route Plan and the medium-term perspective for its implementation constitutes also the time-based scenario for impacts and added values to materialise.

3.2 Future Developments

3.2.1 ***Sustainability.*** Sustainability is not relevant for the CERTESS partnership as a whole but, instead, for the CRs identified and developed as result of partners' joint cooperation and it shall be dealt with after having established the TN associated to each CR.
EICR, as depository of experiences relating to the 29 ECRs already approved, aims at fostering a larger use of project outputs among all participants to each individual route, with the purpose of streamlining procedures and instruments. To this aim, EICR will ensure that the knowledge & knowhow base platform established will be updated also after project end, together with data and information concerning new applications in new regions to promote diffusion and replication. EICR is best placed to ensure that this is continued in future.
In addition, the development of RIPs with the active involvement of local stakeholders and tourist promoters in the project regions will be the main medium-term guarantors for sustaining the project results. To a larger replication effect, final conferences in each partner region will aim to lay the foundation for enlargement of cooperation and replication of practices also in other regions along the reference CR.

3.2.2 ***Methodology***. EICR /CoE will consider reviewing the methodology developed under CERTESS and developing it into reference guidelines to be adopted by EICR in the framework of the EPA strategy and applied both to CRs newly developed or being consolidated.

3.2.3 ***Tutoring***. EICR may consider establishing a regular tutoring service to support route developers/enhancers upon request.

3.2.4 ***Experience sharing***. CERTESS partnership will liaise with BPs information and dissemination centres (such as Culture Watch Europe, NECSTouR, Compendium, IFACCA, ERIcarts and his associated centres of excellence, etc.) to contribute to the wealth of monitoring standards, developments and trends in cultural policy. Synergic cooperation will contribute to increasing the multiplier impact in other contexts.

3.2.5 ***Spin-off projects***. Relations already developed under CERTESS and within the institutional activity of EICR are expected to be instrumental in conceiving and developing future European spin-off projects and local sector plan/actions to be funded with other financial resources.

3.2.6 ***Quality***. Promoting gradually a European-level quality certification procedure and label, subject to periodic confirmation, will reinforce the networking strategy of cooperation.

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‘IREP EN KEMET’ PROJECT: CREATING THE CORPUS OF WINE IN ANCIENT EGYPT

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KEY WORDS: Ancient Egypt, Viticulture, Wine, Tomb scenes, Wine jars, Inscriptions, Legacy, Database, Website

ABSTRACT:

Presented are the research objectives of the project ‘Irep en Kemet’, *Wine of Ancient Egypt*, and the content of the website. This research project aims at documenting the complete corpus of wine in ancient Egypt and analysing the data (iconography, textual sources and artefacts) to unveil the importance of the ancient Egyptian wine culture legacy in the Mediterranean region. At this stage, a bibliographical researchable database relevant to wine, viticulture and winemaking in the ancient Egypt has been completed, a scene-detail database for the viticulture and winemaking scenes in the Egyptian tombs has been recorded, and the collected data will be studied and analysed. Our main goal is to provide scholars with a complete, comprehensive archaeological and bibliographical database for the scenes of viticulture and winemaking depicted in the Egyptian tombs throughout the ancient Egyptian history. The project’s website (under construction) will include all the collected data, the study and analysis, as well as the results of our research.

1. THE ‘IREP EN KEMET’ PROJECT

1.1 Introduction

The ‘Irep en Kemet’ research project’s main goal is to document and analyse, for the first time, the complete corpus of viticulture and winemaking scenes depicted on the walls of the ancient Egyptian private tombs, being the most important data to study the history and legacy of wine production in the Mediterranean region. The traditional European wine elaboration method, which has been used for centuries in the southern European countries like France, Spain, Italy, Portugal or Greece, is considered to come from ancient Greece and Rome. However, the iconographical, archaeological and textual sources from ancient Egypt confirm that the wine was already produced there in the third millennium BC. The scenes represented on the walls of Egyptian private tombs show how the different steps in the elaboration of wine are very similar to the traditional European method. Although several studies and researches were undertaken to resume the viticulture and winemaking in ancient Egypt (Lerstrup, 1992; Lesko, 1996; James, 1996; Tallet, 1998; Murray, 2000; Guasch-Jané, 2008), it has not been compiled and analysed in depth until now.

‘Irep en Kemet’ is a three-year scientific project (2011-2013) that is directed by Dr. Maria Rosa Guasch Jané at the *Faculdade de Ciências Sociais e Humanas* of the *Universidade Nova* in Lisbon (Portugal), and funded by the *Fundação para a Ciência e a Tecnologia* (FCT) of the Portuguese Ministry of Science and Education.

The research team consists of Sofia Fonseca, Archaeologist and Egyptologist, Mahmoud Ibrahim, Egyptologist and Linguist and Maria Rosa Guasch Jané, Pharmacist and Egyptologist.

This paper presents the current stage of our research and the database we are developing, which will be accessible in the project’s website, together with the highlights of the research project.

1.2 Wine in ancient Egypt

The oldest and most extensive documentation about the viticulture and wine production comes from ancient Egypt. In Egypt, wine was a prestigious product consumed mainly by the upper classes and the royal family. Wine was offered in the daily temple rituals, in funerary offerings (Meyer, 1986) and used in medical treatments. Viticulture and winemaking scenes are depicted on the walls of the private tombs from the Old Kingdom (2575-2150 BC) through the Graeco-Roman times (332 BC-395 AD). Thanks to these scenes, we have information about how the wine was made; the scenes showing that the procedures are very similar to the traditional European method (Guasch-Jané 2008; Guasch 2010).

1.3 Wine jars and their inscriptions

Since the Predynastic Period (4000-3100 BC), wine jars were placed in the Egyptian tombs as funerary offerings. During the New Kingdom Period (1539-1075 BC), wine jars (amphorae) were inscribed in hieratic to indicate: the year, the name of the product (*irp* (Erman, 1926) or *shedeh* (Erman, 1930)), the quality, the provenance, the property (royal or private) and the name and title of the wine-maker (Figure 1).

The inscription on the amphora (*Journal d’Entrée* 62303, Cairo Museum (Figure 1)) from Tutankhamun’s tomb (KV 62) at Thebes, reads: “Year 4, wine from the Estate of Aten, in the Western River, chief vintner Nen” (erny, 1965). As Figure 1 shows, the clay seal of this amphora is broken and it is open on the upper part. Like the labels in the modern bottles of wine, the inscriptions on the New Kingdom wine jars give us information about the harvest and wine production (Guasch, 2010).

These inscriptions on the amphorae reveal that the ancient Egyptians considered this information relevant and necessary to be able to distinguish between wines. It was extremely important to know the vintage and the provenance of the product.

Figure 1. Tutankhamun's amphora JE 62303. Copyright: Maria Rosa Guasch Jané, with permission of the Cairo Museum

However, it is curious that no mention was made concerning the colour of wine, either white or red, on the inscriptions or any other documents.

The symbolism of the Egyptian wine was based on its red colour, not only because of the relation established between wine and the blood of the resurrection god Osiris, but also because of the reddish colour of the River Nile during the annual flood -with ferruginous sediments coming from the Ethiopian mountains-, when the harvest time for grapes started (Poo, 1986; 1995). In the papyrus of the royal scribe Nakht at the British Museum in London (BM 10471), a vine is leading to the nose of god Osiris as a symbol of resurrection. This symbolism is still in use in Coptic iconography today.

The Egyptian mythology related the wine only to the red colour, and no textual references to white wine –or to red wine- from the Dynastic period (3100-343 BC) have been found in Egypt up to now. The first mention of white wine in Egypt is from Athenaeus of Naucratis, who lived during the 3rd century BC, in his book *The Deipnosophistae*, where he explains that Mareotis wine, in the area of Lake Mariut near Alexandria, was "excellent, white and enjoyable, aromatic…" (Athenaeus, 1961).

In order to study the kind (colour) of the wines that were made in ancient Egypt, an analytical method (Guasch-Jané, 2004; 2008) for archaeological residues of wine was developed using the liquid chromatography mass spectrometry in tandem (LC/MS/MS) technique. Two compounds were identified in archaeological residue samples from Tutankhamun's amphorae: tartaric acid, as grape marker, and syringic acid derived from malvidin, the latter being the main compound responsible for the red colour of grapes and wines, as red grape marker (Guasch-Jané, 2004; 2006a,b). The results of analysing residue samples from Tutankhamun's amphorae revealed that in ancient Egypt red and white wines were given the name *irp* (Guasch-Jané, 2006b; 2008).

The analytical results added new information to the inscription on the amphorae: about the type of wine they contained. There was a red wine in Tutankhamun's amphora Cairo Museum *JE* 62314 (Guasch-Jané, 2006b; 2008) with the inscription "Year 9, wine of the Estate of Aten of the Western River, chief vintner Khaa", and a white wine was contained in Tutankhamun's amphora JE 62316 (Guasch-Jané, 2006b; 2008) with the inscription "Year 5, wine of the Estate of Tutankhamun, ruler of Thebes in the Western River, chief vintner Khaa".

The results of these analyses also confirm that in Egypt, during the New Kingdom Period, three kinds of grape products were made (Guasch-Jané, 2008): red wine, white wine and the *shedeh*, a red wine with a different preparation.

The origin and nature of the *shedeh*, which has no translation, was a mystery since a century ago, with pomegranates or grapes having been proposed as a raw material. According to Papyrus Salt 825 (BM 10051) of the Late Period (715-332 BC), the only text found so far that mentions the elaboration of the *shedeh*, it was filtered and heated; nevertheless, due to a damage in the Salt papyrus, the botanical source of *shedeh* remained unknown (Derchain, 1965; Tallet, 1995; Guasch-Jané, 2008; Tallet 2010).

The results of analysing a sample of a residue from the *shedeh* amphora found in Tutankhamun's Burial chamber (JE 62315, Carter no. 206), bearing the inscription "Year 5, *shedeh* of very good quality of the Estate of Aten of the Western River, chief vintner Rer" (erny, 1965) confirmed that *shedeh* was a red grape wine (Guasch-Jané, 2006a; 2008).

Recent research suggested the use of the three amphorae found in Tutankhamun's Burial chamber (containing a red wine, a white wine and *shedeh*, respectively) were for the King's three-step resurrection ritual (Guasch-Jané, 2011).

2. VITICULTURE AND WINEMAKING SCENES

2.1 Scenes in the Egyptian tombs

The reliefs and paintings in the ancient Egyptian private tombs depict the different steps of viticulture and winemaking including grape harvest, treading, pressing, fermentation, closing the jars, stamping and labelling the jars, and finally storing the jars in the cellar (Murray, 2000; Guasch-Jané, 2008).

In the scene from Nakht's tomb (Figure 2) at Thebes, dating to the Eighteenth Dynasty (1539-1292 BC), the grape harvest and winemaking are represented. To the right, the scene shows two workers picking up the red grapes by hand and putting them in baskets. To the left, a group of four men are pressing the grapes in a vat with their feet and, besides this, there is a man taking the red juice (the must) that flows out. On the top, the amphorae are sealed with a mud stopper.

Figure 2. Nakht's tomb (TT 52) in Sheikh Abd El-Qurna, Thebes

Regarding the presence of white grapes in the iconography, it is still under discussion. It has been suggested that a tomb from Deir El-Bersheh of the Middle Kingdom Period (1975-1640 BC) may show the production of white wine, since the pressing scene directly follows the harvesting scene where greenish-coloured grapes could be represented (Montet, 1913; Murray, 2000).

The elaboration of the *shedeh* represented in the scenes is also doubtful, and there is a unique reference from the tomb of Baqet III (no. 15) in Beni Hassan that might show a filtering and a heating process (Tallet, 1995).

Our project starts the documentation of the corpus of wine in ancient Egypt with the viticulture and winemaking scenes, not only because of the extensive information they provide, but also for many aspects that are less studied. The types and forms of the vines that are represented in the scenes, and the different heights of the vine tree or its shape are still not fully studied and classified. The same for the workers involved in the grape harvest, the way they picked the grapes as well as the kind of baskets they used for transporting the grapes to the press.

Furthermore, the type and material of the press (or deposit) where the grapes were treaded needs to be studied in-depth, because these scenes are the only references as no archaeological evidence has been found. Another aspect we aim to study is the second extraction of the grapes juice (and colour) using a sack-press.

The fermentation process and the closing of the wine-jars, or the strict control of closing and labelling wine-jars during the New Kingdom Period, revealed by the amphorae and their inscriptions, are even more interesting aspects to be investigated.

2.2 Documenting the scenes

Our team is developing a database in two different parts: the bibliography and the scenes of viticulture and winemaking. We are documenting all the viticulture and winemaking scenes in the Egyptian tombs, including the iconography and the texts associated to the images (Fonseca, 2012). The different elements of the grape harvest and wine production that are depicted in the tombs will be analysed, classified and then compared to the traditional European winemaking method.

The research methodology includes the bibliographical database with all the books, articles, websites and on-line articles as well as existing databases related to wine, viticulture and winemaking in ancient Egypt, and the scenes database with all the iconography and texts related to viticulture and winemaking in the Egyptian private tombs from all archaeological sites in Egypt (Fonseca, 2012).

The scenes will be classified according to type, condition, image, period and name of the tomb owner. The wine production and any representation of the three kinds of wines (white wine, red wine and *shedeh*) will be investigated.

The hieroglyphic texts accompanying the scenes will be studied, categorized, and the translation and commentary will be included.

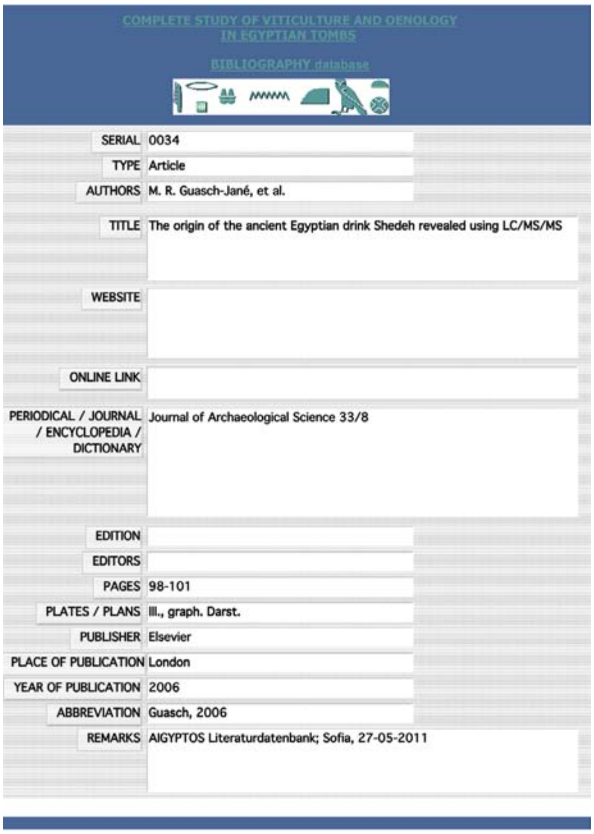
Moreover, the titles of the owners of these tombs having viticulture and winemaking scenes will be studied to unveil the existence of wine-makers, and to know the different specific titles related with wine production.

3. THE PROJECT’S WEBSITE

3.1 Bibliographical database

The project’s website will first include the database with the bibliography related to wine, viticulture and winemaking.

The bibliographical database, which has now more than 180 entries, see example in Figure 3, includes the following items about each reference: serial number, type of article/book, authors, title, website, online link, periodical/ journal/ encyclopaedia/ dictionary, edition, editors, pages, plates/ plans, publisher, place of publication, year of publication, author abbreviation and remarks (Fonseca, 2012). It is being recorded in Excel Sheet and presented by Filemaker Pro11 software.



COMPLETE STUDY OF VITICULTURE AND OENOLOGY
IN EGYPTIAN TOMBS

BIBLIOGRAPHY database

SERIAL	0034
TYPE	Article
AUTHORS	M. R. Guasch-Jané, et al.
TITLE	The origin of the ancient Egyptian drink Shedeh revealed using LC/MS/MS
WEBSITE	
ONLINE LINK	
PERIODICAL / JOURNAL / ENCYCLOPEDIA / DICTIONARY	Journal of Archaeological Science 33/8
EDITION	
EDITORS	
PAGES	98-101
PLATES / PLANS	Ill., graph. Darst.
PUBLISHER	Elsevier
PLACE OF PUBLICATION	London
YEAR OF PUBLICATION	2006
ABBREVIATION	Guasch, 2006
REMARKS	AIGYPTOS Literaturdatenbank; Sofia, 27-05-2011

Figure 3. Bibliographical database

3.2 Scene-detail database

The database of the scenes of viticulture and winemaking in the ancient Egyptian private tombs (see Figure 4), in process, will include the following items about each scene (see Figure 5): record number, scene description with the different steps according to the theme, that is, viticulture or winemaking. The steps represented in the viticulture scenes include: vinery, taking care of the vine, grape harvest and counting the baskets. In the winemaking scenes, the steps represented are: transporting grapes to a press, pressing grapes, heating and filtering, pressing the remains in a sack press, filling wine jars, fermentation, offerings to goddess Renenutet, wine tasting, sealing the wine jars, labelling wine jars, counting wine jars, transporting wine jars to a cellar, refrigeration during fermentation, and storing wine jars in a cellar.

The scene-detail database (Figure 5) will also include: scene details, annotations, scene type and scene condition, text (inscriptions and translation) and image/photo.

Moreover, the scene database (Figure 6) will include: dating (period, dynasties and kings), location which includes: a) provenance with governorate, archaeological site, tomb name and number and location inside the tomb; b) present location, with same as provenance, if it's a museum then location inside the museum and inventory number, and others if it's not a museum. Finally, the tomb information (type of tomb, tomb’s owner and name and titles of the tomb’s owner) will be included. At the end, the bibliographical references related to the scene will be listed.

The data is being recorded in Excel Sheet and presented by Filemaker Pro11 software.

Figure 4. Global image of the scene database.
Copyright (photos): Griffith Institute, University of Oxford, and Abteilung Ägyptologie, FB III, Universität Trier

Figure 5: Scene database, detail (left side). Copyright (photos): Griffith Institute, University of Oxford, and Abteilung Ägyptologie, FB III, Universität Trier

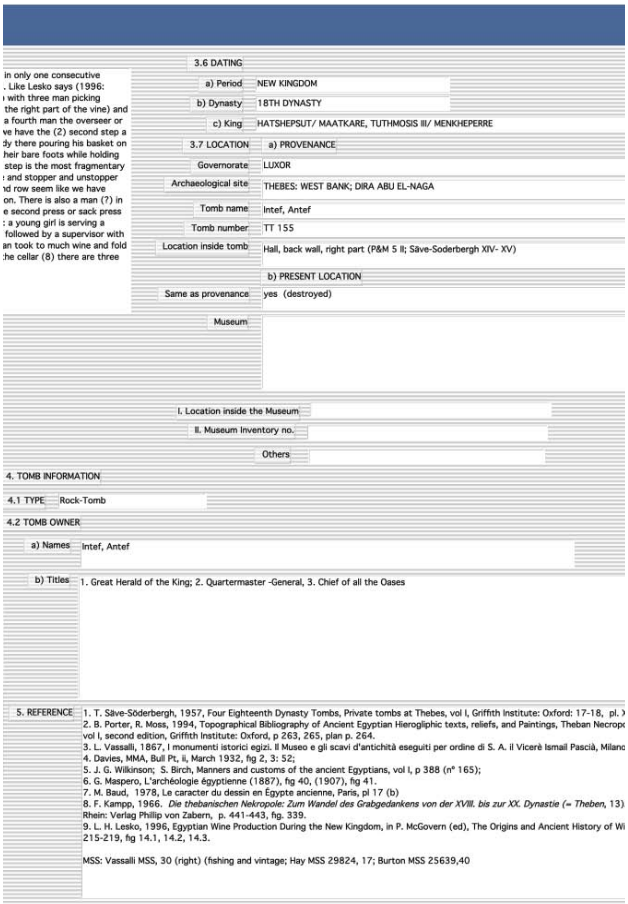


Figure 6: Scene database, detail (right side)

3.3 Technology transfer and dissemination

Besides the database with the corpus of scenes of viticulture and winemaking and the bibliography at the first stage, the project will develop a website, which will include all the material related to the research and the scientific and non-scientific dissemination of the results. The research manuscripts that we plan to publish in international *peer-reviewed* journals with the results of the scientific research will be included in the website. Articles presenting the results and addressed to the public will be also included in the website, as well as articles in journals specialised in Egyptology, archaeology or oenology, magazines and in the mass media. Furthermore, the communications in congresses presenting the research results of this project will be posted in the website, as well as conference proceedings, and lectures to the scientific community and to the general public.

3.4 Further research

We plan to extend our research to the other aspects related to wine that are represented in the ancient Egyptian iconography: the daily life scenes of wine drinking in banquets and religious festivals. Scenes depicting wine consumption were popular motifs in private tombs of the Eighteenth Dynasty (1539-1292 BC) at Thebes. Furthermore, we also aim to document the scenes of wine-offering in rituals depicted in tombs and temples, as well as the archaeological artefacts (wine jars and related objects) which will be further included in the website. The expected results are to relate the process of wine elaboration of the ancient Egyptians to the traditional European method and to unveil the ancient Egyptian wine culture legacy in the Mediterranean through the compilation and study of the iconography, texts and artefacts.

4. CONCLUSION

The final and main result of the 'Irep en Kemet', *Wine of ancient Egypt*, project is to document the corpus of wine in ancient Egypt. At this stage, we are compiling and studying the viticulture and viticulture scenes in the Egyptian private tombs. Our goal is to publish an on-line comprehensive and researchable database of the viticulture and winemaking scenes in the ancient Egyptian tombs, considering all the data regarding the scene and the tomb where it was found, and the bibliographical references available. The database will be available on-line for Egyptologists, students or the public interested in this subject. In the near future, we plan to extend our project to include all the scenes related to wine in the ancient Egyptian daily life and rituals, depicted in temples and on funerary stelae and artefacts.

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INVESTIGATIONS ON A BULL'S HEAD FROM PYRGOS/MAVRORAKI (LM) TO DESIGN THE BIODIVERSITY OF CYPRUS IN EARLY-MIDDLE BRONZE AGE.

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KEY WORDS: Bronze Age, Palaeoenvironments, Sedimentology, Paleopalynology, Biodiversity, Hybridism

ABSTRACT:

The site of Pyrgos-Mavroraki near Limassol in Cyprus, destroyed by an earthquake in 1900-1850 B.C., is situated in an elevated position in the center of a vast settlement of the ancient and Middle Bronze Age before the Calcolitic period. The unchanged position of the structures and the finds, that remained unknown for 4000 years near the homonym village, offers a unique opportunity to carry out sedimentological, paleopalinolocical and archeobotanic investigations on totally uncontaminated materials. The results of the sedimentological and paleopalynology investigations and the characterization of other plants micro remains found in the samples from the bull's head SL (PY 09 D.10 B) make it possible to formulate some considerations on the vegetation in the ancient landscape.

Introduction:

Pyrgos-Mavrorachi is an archaeological site that has visual structures to enhance understanding. The ruined state of the site has acquired significance in its own right, and today the site forms part of a landscape that is publicly accepted as having special cultural significance. All the area is distinguishable by heritage resources, which should have the potential to become an interpretive and educational instrument for the public and a tourist attraction.

The Bronze Age settlement is in on elevated position, situated on the slope of a low hill (Mavroraki) in the middle of valley formed by a crossing of streams. In its proximity, there is the large harbour of Amathunte and three smaller sheltered anchorages.

The site was located in 1995, surveyed in 1996-97 and excavated during the years 1998-2009-2012 by the Italian Archaeological Mission of CNR at Pyrgos/Mavroraki in Cyprus.

The excavations brought to light an important Middle Bronze Age industrial settlement (2^{nd} millennium BC) in an exceptionally state of in situ preservation material, overlying a previous occupation of the late 3^{rd} millennium BC. Consequently, Pyrgos has significantly enriched our knowledge of the development of Limassol region and has provided more solid foundations for our understanding of Early-Middle Bronze Age Cypriot metallurgy.

The Pyrgos area was classified as protected, by a Department of Antiquities Decision in 2002 and some plots (for an extension of almost 2 hectares) have been expropriated for the excavation. Evidence of the first establishment of people in Early Bronze age has been found along the ridge of the side of the excavated area, on the medium slopes of the Mavroraki hill. They consist in architectural remains and assemblage of pottery that attest to the existence of earlier phases, belonging to dwellings destroyed by later buildings constructed on a sort of terrace North to the Pyrgos river.

The inclination of the hill helped the distribution of the buildings on different levels and their reuse and superimposition by later buildings.

The dimension and distribution of the Pyrgos/Mavrorachi settlement was calculated and mapped in 1999-2000. Recurrent surveys, carried on during the excavation seasons, revealed the settlement was distributed near the the western branch of the river Pyrgos, for a length of 700 metres, between the locations of "Kolla" and "Perivolia", including the small terrace of "Aulaki", on the southern side and the Mavrorachi hill 500 metres west to the old "koriò". The number of stone tools and fragments of pottery guided the estimation of the settlement length. The documentation recovered designs of a specific pattern of metallurgical settlement in which the guide element is given by the emerging presence of copper outcrops and watercourses, directly connected to the main activity of the inhabitants. The nearest mines localised in the surrounding area of the Pyrgos village create an axis that ran parallel to the coastline, an identifiable large way of copper with the alignment of the villages of Monagroulli, Monì, Pyrgos, Parekklisha and Aghios Thyconas. The recovery of galleries of ancient cultivation testifies the millenarian exploiting activity of the zone, turns to the achievement of the mixes sulphides outcrops.

This it has been confirmed from the analyses of the slag of E-MB age recovered at Pyrgos. Before the discovery of the Mavrorachi complex, the first small-scale copper production was estimated to have started in Cyprus after the second half of the 2^{nd} millennium BC.

However, the Pyrgos evidence points to an earlier date and demonstrate that centuries before that time, the Middle Bronze Age society was able to organise an industrial production of copper (Belgiorno, 2004, 2009). The site is important not only for its industrial identity but for the intact prehistoric levels, buried by the sudden collapse of the walls after the earthquake. This particular condition allows, through archeology, archaeometry, paleobotany, paleozoology and etnoarchaeology investigations to reconstruct the II millennium BC process of metallurgy, agriculture, medicine and textile production. A second building was discovered and brought to light in 2008 south of the industrial area.

This is a unique construction, consisting of two rooms arranged in a triangular area.

1 .Selection method: casual randomization

The head (Fig. 1) is 28 cm. long and 10 cm wide; the maximum height from the poll to the base of the cheek is 11 cm. A piece of the horns was also recovered (7 cm. long, 3 cm. wide, 4 cm. thick).

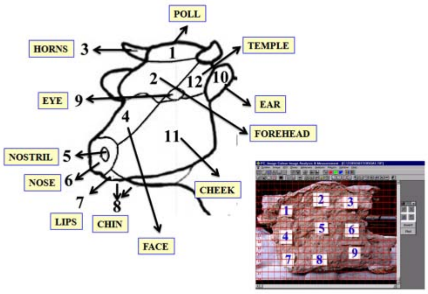

Figure 1, Anatomical areas of the bull's head to the side of the micro-areas grid for casual randomization.

Ten micro cores of material were selected with the randomization method, and a grid of 25 micro areas was set up, corresponding to all the recognizable parts of the bull’s head. Simple random sampling is done by extracting a certain percentage of units from identified and numbered micro areas by a method that guarantees the randomness of the extractions. A classical way to obtain randomness is to pick out a number (as in lotteries) from a list (the sampling list) of all the numbered micro areas (Tab. 1). In our case, we used an appropriate computer program and checked the randomness of the sample against tables that generate random numbers (Spiegel Murray, 1961). A Microsoft Excel spreadsheet can be used for this purpose, inserting the function =RANDOM (), which gives a random decimal number between 0 and 1. We used the formula =INT(RANDOM ()*25+1, which gives a random number between 1 and 25.

ID	ANATOMICAL AREA
T25	Cheek left
T12	Temple right
T8	Pool left
T3	Base horn left
T15	Neck right
T4	Ear right
T16	Forehead left
T6	Face left
T11	Nose right
T1	Pool right

Table 1. List of numbers extracted.

Simple randomizations, like other sampling methods, is valid for sampling in multiple disciplines, and it offers two advantages. First, it satisfies the requirements of good sampling: all the micro areas have the same probability of being chosen. Second, it makes it possible to assess the reliability of the results obtained.

2. The sedimentological investigation

The sediments were treated with H_2O_2 (hydrogen peroxide) at 36% to remove organic matter. Subsequently they were mixed with a solution of $(NaPO_3)6$ (sodium hexametaphosphate) and placed under stirring for 48 hours. Various density measurements obtained with calibrated reference hydrometers (Mériaux method) were carried out over 24 hours, in a sedimentation tank at a controlled temperature. To be able to determine how the natural landscape in the Pyrgos area changed over time, a preliminary sedimentological investigation was performed on the micro samples selected from the bull’s head discovered in SL PY 09 D10B. The granulometry of the ten micro samples (Fig. 2) can be defined silty clayey with low percentages of sand. Particular interest is the digenetic process that affected the head of the bull after its initial deposition, the finer particles of clay and silt have replaced the original organic tissues with lithification dug around the complex, also incorporating different fragments of pottery in the SL investigated.

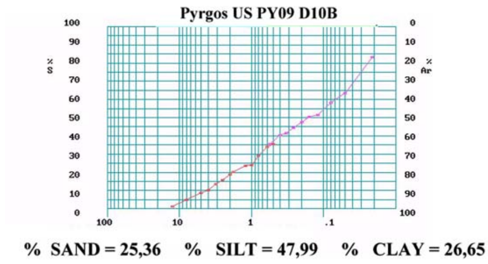

Figure 2, Sedimentological curve of SL PY 09 D10B.

The finest clay and slime particles replaced the original organic tissues, lithifying the whole excavated complex and incorporating pottery shards present in the SL. In this micro environment, the shallowness of the interment of the heterogeneous complex surely intensified the bacterial activity that broke down the original organic matter. The morphoscopic analysis of the granulometric fraction >2 mm shows a series of windborne quartz crystals that confirm the site’s exposed character (Lentini, 2009).

The diagrams of the granulometry and the presence of human elements show that the site was occupied continuously, due essentially to two main interlinking features one of the natural origin and the other of human origin that contributed to the build up of the deposit.

3. Paleopalynological results

This study was based on the results obtained from an initial screening of the texture of the sediments, the pH measurements and the quantity of organic matter. To protect the samples from external pollution, the paleopalynological extraction was performed with methods that prescribe the use of HCl and HF in a sterile environment. To calculate absolute pollen frequencies, the number of granules per gram of sediment a tablet of *Lycopodium* was added to each sample.

The average number of pollen granules counted per micro sample ranged from 984 to 1548. The pollen spectra are based on the total number of granules counted (Walker, Pittelkow,1981). The findings are shown in table 2, which lists the identified species and their respective percentages, in their order of immigration, and also in two graphs (Figs. 3 and 4).

The first refers to the AP NAP ratio (arboreal and non arboreal plants) found by adding up pollen from trees and grassy plants, the. second shows the species most represented. Figure 3 shows the percentage palynological graph produced with Tilia and Tilia Graph software **(**Grimm, 2002). Further information about identification of

TAXA	T25	T12	T8	T3	T15	T4	T16	T6	T11	T1
Irano-Turanic										
Cedrus sp.	3,66	3,63	3,67	3,57	3,34	3,2	2,96	3,18	3,67	4,24
Pinus sp.	6,59	6,8	6,56	6,35	7,17	6,99	6,57	6,92	7,35	7,24
Juniperus sp.	6,92	4,84	4,65	4,57	4,26	4,22	4,19	4,23	3,97	3,66
Cupressus sp.	6,51	4,16	5,08	5	4,83	4,66	4,98	4,52	4,41	3,95
Riparian vegetation										
Alnus sp.	3,74	3,85	3,39	3,21	3,55	3,5	3,75	3,53	3,31	3
Ulmus sp.	3,25	2,15	2,55	2,58	2,84	2,77	3,18	2,89	3,16	2,93
Popolus sp.	3,09	3,85	3,46	3,57	3,43	3,24	3,75	3,48	3,49	3,64
Salix sp.	1,24	1,89	1,97	2,5	2,2	2,11	2,09	2,19	2,2	2,34
Juncaceae	1,20	1,10	1,33	1,06	1,18	1,20	1,16	1,18	1,07	1,04
Ferns	0,81	0,91	1,06	1,14	1,28	1,46	1,44	1,69	1,62	1,46
Nymphaceae	1,05	0,83	0,99	1,07	1,56	1,75	1,37	1,41	1,54	1,61
Vitis sp.	3,09	3,17	3,39	3,21	3,55	3,5	3,9	3,95	3,97	4,24
Mediterranean										
Quercus sp.	3,09	3,78	3,46	2,85	3,41	2	3,32	3,39	2,31	3,51
Prunus s.p.	2,85	3,63	3,53	3,21	3,55	3,71	4,04	4,23	3,67	3,95
Olea sp.	1,96	1,83	1,20	1,85	1,54	1,28	1,2	1,08	1	1,45
Pistacia sp.	2,28	3,4	3,39	3,28	3,97	4,22	3,97	4,02	3,97	2,57
Laurus sp.	4	4,46	3,03	4,07	3,83	3,86	3,61	3,81	3,75	3,58
Myrtus sp.	3,39	2,71	4,58	4,35	3	4,44	3,2	3,08	3,89	3,66
Genista sp.	3,17	3,1	3,1	1	2,7	2,55	2,53	2,54	2,35	2,41
Crops										
Cerealia	4,56	6,12	6,28	6,85	6,03	6,41	5,85	6,21	6,61	7,17
Linum sp.	2,85	3,02	3,03	3,21	2,98	2,91	2,89	2,75	2,57	2,27
Anthropocore species										
Graminaceae	3,25	5,52	4,8	4,35	4,19	4,66	3,97	3,95	3,97	4,02
Artemisia sp.	3,4	3,25	2,82	3,21	2,48	2,26	2,74	2,82	2,79	2,63
Urtica sp.	3,58	1,89	2,12	2	2,13	2,04	2,02	2,12	1,76	1,83
Autochthonous species										
Papaver sp.	3,09	3,1	3,1	3,28	3,48	3,28	3,25	2,89	2,94	2,78
Lilium ssp.	2,03	1,59	1,76	2	2,13	1,97	2,24	2,26	2,13	1,98
Hedysarum ssp.	2,93	2,65	2,68	2,85	3,19	2,99	3,1	2,82	2,5	2,27
Tulipa ssp.	1,71	1,74	1,76	1,71	2,06	2,18	2,02	2,19	2,2	2,05
Potentilla sp.	1,62	1,44	1,55	1,78	1,99	2,26	1,52	1,76	2,06	2,19
Iris ssp.	1,46	1,51	1,76	2	1,56	1,82	2,02	1,48	1,62	1,76
Gagea ssp.	1,79	1,89	2,12	2,28	2,06	1,97	2,17	2,19	2,57	2,78
Narcissus ssp.	1,22	1,36	1,27	1,42	1,35	1,46	1,52	1,41	1,76	1,83
Rosa ssp.	2,52	2,87	3,1	2,71	1,28	1,38	1,44	1,55	1,69	1,76
Spores	0,81	1,13	0,71	0,85	1,06	1,02	1,3	1,41	1,32	1,46
Indeterminate	1,14	0,83	0,78	0,92	0,85	0,73	0,72	0,85	0,81	0,73

Table 2. Summary table percentage of *Taxa* identified with the paleopalynological analysis.

several palynological zones. In the phases represented the micro samples that were examined, trees such as *Cedrus*, *Pinus*, *Cupressus* and *Quercus* are present in significant percentage. They are native to the Irano-Turanic region and are reported as growing wild in neighbouring areas. All species reported during the first paleopalynological investigations of SL PY 04H6 are found today in the spontaneous vegetation of Cyprus, on the Troodos massif. The analytic data seem to suggest the Mediterranean steppe forest with pollens from *Juniperus*, *Pistacia*, *Olea*, *Laurus* and *Myrtus*, thanks to the hot and humid climate. The woodland component includes Mediterranean evergreens such as the evergreen or Kermes oak (*Quercus*) and other oak species, olive trees (*Olea* sp.,), pistachio trees (*Pistacia* sp.) and plum trees (*Prunus* sp.), which were also identified in the paleopalynological study of the SL PY 04H6

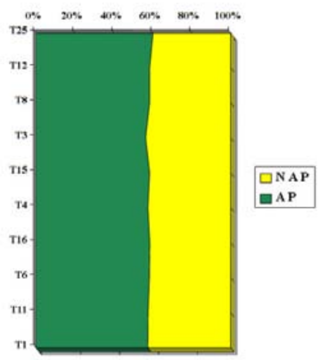

Figure 3, Cumulative AP NAP summary diagram.

(Lentini, 2009b); as noted above, these trees remain from an older, Mediterranean type phase. In an earlier and more humid phase, this Mediterranean type plant alliance had probably managed to spread farther south than the area where it exists today. The third part of the graph shows the natural arboreal vegetation representative of a streamside environment: willows (*Salix*), poplars (*Populus*), alder (*Alnus*), elm (*Ulmus*) and grapewine (*Vitis*) in association with water loving plants such as rushes (*Juncus),* Ferns and water lilies (Nymphaceae), which testify to the strong influence of hydrological features on the island of Cyprus.

3.1 Anthropisation indicators

The evidence for these factors, plotted in the central parts of the palynological graph with a significant portion of spectra, due to the cultivation of grain and textiles plant (Greig, 1982), produces curves with indicative trends when, as in this case, they belong to anthropised palynological contexts (Lentini, 2009). The morphobiometric study of these pollen types was recently recast with the aid of an image analyser. Automatic counts and measurements of morphobiometric features (as proposed by S. T. Andersen) were made for *Cerealia* and the other Graminaceae. The presence of *Cerealia* is evidenced by four types of pollen. Pollen from plants belonging to the *Hordeum* group: *Hordeum vulgare* L. (cultivated barley), *Triticum monococcum* L. (einkorn wheat) and certain wild species.. Pollens from wheat and oats, the *Triticum/Avena* group, are present from the all microsamples and become a constant presence on the graph. The analytic procedures found no evidence of contamination. The state of preservation of these pollens is not such as to justify their attribution to a period different from that of the rest of the characterised species, and there appeared to be no phytogeographic reason to do so. As a result, they have been included as contemporary with the rest of the spectra, even if their trend can be thought a case of under representation that can be associated with the ancient forms of agriculture (Lentini, 2009). The palynological morphologies found in the micro samples seem to come from the moment of maximum expansion of the farmland vegetation, but the pollens from *Genista*, *Artemisia*, *Chenopodium* and Graminaceae already appear in this phase, all these are anthropochory that precede the formation of a garigue. This environmental context was essentially a combination of three elements the natural landscape, farmland and products selected by the frequenters of the site but a fourth element eventually came in it consisted of species such as *Hedysarum*, *Tulipa*, *Potentilla*, *Iris*, *Crocus*, *Papaver*, *Lilium*, *Narcissus* and *Rosa* sp.. The SL PY 09 D.10 B sector seems to have been an area where only selected floral species were brought in and preserved. The list of flowers resulting from the paleopalynological tests provides evidence of the native and endemic species present on the island of Cyprus (Lentini, 2099b).

3.2 Geobotany and biodiversity in the Early Bronze Age

The results of the sedimentological and palynological investigations and the characterization of other plants micro remains found in the samples from the bull's head (SL PY 09 D10 B) making it possible to formulate some considerations on the vegetation in the ancient landscape.

3.3 Autochthonous herbaceous species

Hedysarum sp.
This plant grows wild throughout the Mediterranean area, where it is thought it had its origins.

Hedysarum cyprium.
A member of the Fabaceae family, is the autochthonous species in Cyprus, today it grows wild on the vast plain of Mesaoria. This part of the island is historically one of the most affected by human activities and above all, one of the most irrigated and farmed. In the past documented deforestation, wildfires and fallowing caused soil erosion.

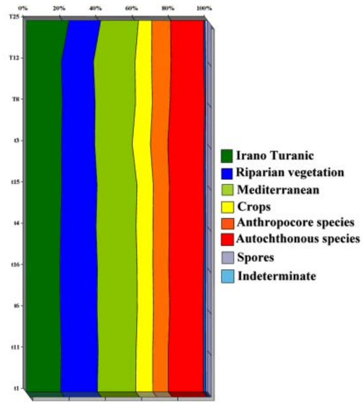

Figure 4, Palynological diagram divided in elements.

These developments led to the formation of garigue associated with anthropochory species, mainly *Quercus coccifera*, *Olea europea* L., *Olea sylvestris* and Chenopodiaceae-Amaranthaceae.

Crocus cyprium, *Crocus veneris* and *Crocus hartmanianus.*
The *Crocus* genus bulbous plants with linear leaves is extremely variable in its cytology (cell morphology and internal structure), since it has a large number of chromosomes (polyploidia). The chromosome numbers range from 2n = 6 to 2n = 30. This circumstance leads to a high degree of segregation among local species (groups of geographically isolated individuals can evolve quickly into more or less different forms), and consequently, to a very high difficulty in classifying them. These grassy perennials grow everywhere in Cyprus. *Crocus cyprium* appeared for the first time between the illustrations of the *Codex Aniciae Julianae*, also known as the *Codex Vindobonensis*, the *Codex Byzantinus* or the Vienna Dioscorides, the oldest and finest illustrated copy of the Greek physician Dioscorides's *De materia medica*.

Papaver sp.
The presence of *Papaver* is especially interesting. Poppies grow wild in the Mediterranean area, and are generally present on the edges of tilled fields. There are five autochthonous species in Cyprus, *Papaver argemone* ssp. meiklii [Kadereit – Syn.: P. minus sensu Meikle], *Papaver rhoeas* ssp. *cyprius*, *Papaver rhoeas* var. *oblongatum* and *Papaver orientale* var. *bracteatum*. They are distributed over the area from the Troodos and Pentadactyl mountains to Stavrovouni, and have also been reported near the seaside in Paphos and Limassol.

Tulipa cypria.
This bulbous perennial is native to Cyprus, it grows at medium altitudes in the Troodos mountains.

Euphorbia veneris.
This perennial species contains a poisonous latex that is still used in the pharmaceutical industry. It grows wild in calcareous soils in the Troodos mountains and in the glades of the Paphos forest.

Rosa sp.
The rose genus includes around 150 species, many varieties and a huge number of hybrids. They grow wild about the medium altitudes of the Troodos mountains and can appear in the form of bushes, low trees and creepers.

Iris sp.
A bulbous perennial whose flowers can be white, violet or yellow. It blooms in the spring in the medium altitude glades of the Troodos mountains. It is used for medical purposes and in making perfume.
Potentilla reptans .
A perennial species with woody rhyzome and solitary flowers, usually yellow. It grows wild in the territories of Prodromos, Trikoukia, Myrtou and Rizokarpaso, and blooms between May and June.
Lilium candidum (Fig.5).
This species has a scaly bulb and produces white flowers (solitary or grouped); it grows wild in all the island's micro environments.

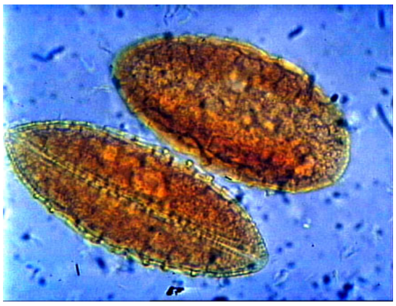

Figure 5, Pollen types of *Lilium* sp. (40 X).

Narcissus tazetta - A bulbous species that grows wild in the rocky soil of Ayia Napa and Karpassia. The flowers are unusual in that they bloom in bunches atop leafless stalks.

4. Phytoliths

The phytoliths like the pollen grains and sediments have a very useful function in the analysis, since they are always in significant quantities. It is also very well preserved in ancient sediments and have shapes and sizes that generally allow you to identify the genus or species that generated them. Analysis of these siliceous crystals, together with the paleopalynological investigation can provide additional information for the reconstruction ancient environment. For morphological descriptions has been used the Twiss P.C. nomenclature (Twiss, et *alii*, 1969). With the use of this classification is not always easy to determine the differences in morphological parameters. Generally, the morphological parameters are considered complementary to more specific studies on the plant epidermal tissues that have undergone a process of silicification. Moreover, in the observations and calculations of morphologies can be expected randomization of microsamples examined.

Figure 6, Quadrangular morphology (40 X).

The group is composed of phytoliths documented crop species such as *Triticum* sp. (Fig.6) and *Hordeum* sp.. From the characterization of phytoliths anthropochory species such as *Bromus* sp. can be observed, *Carex* sp. and *Juncus* sp. is among the species that makes up the riparian vegetations.

5. Textile fibers

The fibers and organic materials found were the subject of chemical and morphobiometric analyses to obtain a detailed definition of their origin and evolution. The features examined have been compared with fibers from the same species of different collections. The fiber and woven materials were treated with a solution of glycerin and 50% bi-distilled water.

Figure 7, Mineralized fiber of cotton (10X).

The fibers and woven materials, all of which were particularly deteriorated, were consolidated with a 5 % vinyl acryl nitrile emulsion. The morphobiometric study of the different fibers was done using an image analyzer. We initially examined 45 morphologies 20 of cotton (*Gossypium* sp. - Fig.7), the most relevant of the vegetable fibers with fibers of *Linum* sp. (10) and 15 filaments of wool.

6. Spores

Spores were found of fungi (*Alternaria* – Fig.8, *Epicoccum*, *Stemphyllum*, *Drachslera*, *Fusarium* and *Didymella*) typical of nitrophilous environments and often present in quiescent elevated structures (walls and artifacts of different nature).

Figure 8, Spore of *Alternaria* ssp. (40X).

The outdoor spores had been deposited in the indoor sediments by climatic vectors such as wind and water, and by the comings and goings of humans.

7. Stomata and structures of the lower epidermis of leaves

During the paleopalynological analysis of samples T3 (Fig. 9), T6, T8 and T16 were shown some structures and stomata epidermis of the underside of some leaves in SL PY 09 D10 B

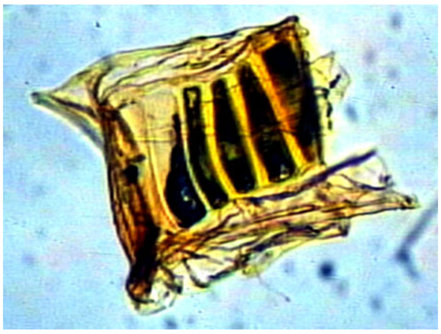

Figure 9, Stomata cells (40X).

The presence of these biological structures, may indirectly confirm the hypothesis of a particular area of the archaeological site of Pyrgos, where they were selected plant species. Furthermore, the position of the stomata open showed a cool damp climate.

8. Hybridism and vegetation in Cyprus

The presence of a significant number of autochthonous species in Cyprus in the Early Bronze Age poses a number of questions for both the paleopalynological and the archaeological investigations, the natural hybridization in an isolated and genetically segregated environment and on the possible intentional selections made by the island's sedentary population. The difficulty of interpreting evidence in this context was described during the analysis of sediments contained in a pottery vessel found in SL PY03 H5L6 (Lentini, 2009b) problems were caused by the presence of mono and sesquiterpene hydrocarbons and their non volatile derivatives in *Citrus* oil. The little documentation existing on the origin of this species located generically between the eastern Mediterranean and the subtropical east makes its classification very complex. Based on recent genetic applications, there exist only three species of Citrus; all the other members of the genus that used to be considered species or subspecies should actually be considered natural hybrids. The hybridism found in this context probably derives from cross-pollinations between different species. In general, botanists distinguish between different types of hybridization, depending on the systemic affinities between the crossbred species. Hybridization between varieties of the same species is fairly common. In many cases, it is a natural process caused by a whole series of accidental factors. Cross fertilization is usually a two way process, if the pollen succeeds in fertilizing the oosphere. Statistically hybridization produces individuals that are more vigorous than the two parent species and have better organoleptic and biochemical qualities, due to the heterosis effect. When the hybrid ripens and is ready to reproduce its characters begin to separate, according to the laws of heredity. The paleoenvironmental evidence found at Pyrgos in eight years of plant micro and macro vestiges investigation points out a context that included the presence of species whose morphology was halfway between wild species and species being produced by human selection. This aspect of the paleovegetation in Cyprus was showed over the time and by the way biometric measurements of paleoseeds of *Triticum* sp., *Hordeum* sp., *Lens* sp., *Cicer* sp. and *Vitis* ssp., all sifted out of material found in SUs G7L3, H5L6, J6L6, J6L5, J6L6, J5L8, J7L5 and F8L4. Cyprus's location at the southeastern boundary between the Mediterranean region and the Pontic region (the Irano-Turanic element) and the Near East (the Syriac and Nubo Sindic elements - Zohary, 1973) does not seem to have effectively influenced the most important endemic species, in fact they were probably preserved by the island's microclimates and particular edaphic conditions. The preliminary results obtained at Pyrgos suggest that the local climate was cool and moist, as it has been found in other southern Mediterranean sites dating from 1900-2000 B.C.. In those environmental conditions, with a cool and moist temperature, you can find today vegetation at medium and high altitudes, while, in 1900-2000 B.C, they were likely to grow at lower altitudes closer to the sea. Later on the most representative biocenoses gradually moved to higher altitudes, where the environmental conditions were still cool and moist. This happened partly because of the Mediterranean basin climate changing and (Barbero, Quezel, 1979) partly because of the increasingly intense human activities.

Conclusions

The set of results obtained from the micro samples selected from the bull's head discovered in SL PY 09D.10B presents essentially two phases. The first one occurred during a hot and moist climate period characterized by components of the Mediterranean and streamside biome (already reported during the study of the SL PY04 H6 stratigraphic section). The second phase was characterized by the significant presence, in the palinologic record, of grassy and bushy floral species native to the island of Cyprus and associated with the presence of phytoliths, textile fibres and epithelial plant structures that point in this SL to an activity of selection of very particular plant species. The presence of various phytoliths of *Triticum* sp., *Hordeum* sp., *Bromus* sp. and Juncaceae, and the high percentages of floral species, seem to be associated with intentional dynamics, because of the presence of all the elements needed to fabricate floral compositions, decorations, ornaments and garlands.

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MPM GIS PROJECT
REPORT 2010-12 AND ARCHAEOMETRIC PROTOCOLS

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KEY WORDS: Archaeometry, GIS, geological prospecting, landscape archaeology, geo-archaeology, DGPS mapping.

ABSTRACT:

The project is mainly focused on the study of the landscape assessment in the area of Moni, Pyrgos and Monagroulli (Limassol-Cyprus), which represents a very interesting topographical and archaeological area. A large team, including scholars and students coming from different Italian and Spanish institutions, is using the traditional methodologies for studies of landscape archaeology (intensive and judgmental survey, GIS mapping, DGPS location of the sites, studies on typologies, distribution and statistics of pottery finds), in combination with methodologies and technologies integrating information, such as Remote Sensing on aerial photos and on high definition panchromatic satellite photos, geo-morphological reconstruction of the context, archaeometric analysis of the finds and of the building materials, non invasive geo-archaeological prospecting. The project started in 2010 and already at the preliminary stages is giving interesting results. The aim of this paper is the presentation of the project, concentrating here mainly on the archaeometric protocols, analysis and preliminary results.

1. THE PROJECT (O.M.)

1.1 Aims and team

The team of Chieti University, involving both the Centre of the Athenaeum for Archaeometry and Microanalysis (CAAM) and the Department of Psychology, Humanities and Territorial Sciences (DiSPUTer) of the University of Chieti, and the Italian Ministry for Cultural Heritage (MIBAC), has started a collaboration, both on archaeological, topographical and geophysical bases, with the Director of the Italian Mission at Pyrgos, Dr M.R. Belgiorno (ITABC-CNR Rome) since 2008, with limited topographic and geophysical surveys.
However, since 2010, the team started, thanks to permission of the Department of Antiquities of Cyprus, surveying and mapping the territories of Moni, Pyrgos and Monagroulli (Limassol-Cyprus), for a wide and complete study of the landscape assessment of the area, in order to reconstruct the meaning of the changes of the settlement patterns through the centuries, from prehistory till the middle age (Belgiorno, Fossataro, Menozzi, forthcoming).
The team is mainly working in reconstructing the ancient landscape assessment with the application of different technologies and archaeological, geological and environmental protocols, which have been widely tested and codified by our team in some international projects in Libya (Menozzi, Fossataro 2010a), Egypt and Cyprus (Bombardieri, Menozzi, Fossataro 2009, 2010; Menozzi, Fossataro 2010b).

The aim of the project is therefore the study of this territory (Fig.1) which finds its morphological and topographic limits on the hills and ridges to the west of Pyrgos (which represent also the natural and administrative boundary with the municipality of Parekklesia- Limassol), in the area of Monagroulli to the east, in the mountainous slopes behind Mazokambos to the north and the seacoasts to the south, delimiting therefore a territory very interesting for remains, settlements, geological and topographic features.
Considering the lack of mapping and localization of the numerous finds and remains in this territory, the project has been planned for mapping the remains within the area, employing both traditional and instrumental survey of this interesting area in order to produce archaeological maps and GIS, on topographic, cadastral and high definition satellite bases including the main mineral and hydro-geological resources, the ancient road-network and the distribution of ancient sites and finds.
This territorial study is mainly based on a multidisciplinary scientific approach, involving archaeologists specialized in different periods, geo-archaeologists and geo-morphologists, topographers and archaeometrists, guaranteeing a more complete study of the area both diachronically and synchronically, which is generally very rare for survey projects. Moreover, the possibility of limited soundings and excavations as stratigraphic tests allow a more critical interpretation of surface data, generally too partial if analysed just for themselves. The control of the scatter sites and finds coming from the survey is also done using different methods and technologies, such non invasive geo-prospections, Remote Sensing and photo-interpretation, and also including archaeometrical analysis of the main fabric and finds with a specific geo-archaeological survey for mapping the main sources for the pottery locally produced.
The data coming from the researches and surveys of several teams moving in the territory and the results of the analysis are converging in real time in a GIS platform which is organised in several interactive levels, allowing different views of the data and of the territory, with the possibility to change the topographic base on the bases of the needs, switching from the cadastral maps to the aerial view, to the high definition satellites images.
This typology of multilayer approach is particularly important for a research involving more teams working on different fields and strictly collaborating not only within the members of the project, but with the possibility to exchange data, views and methods with other teams working on common bases and with

the Department of Antiquity controlling directly season by season both the territory, the results and even ask for specific researches and areas.

1.2 Study of the territory: methodologies and technologies

The topographic base of the project is coming from the merging of different topographic bases, cadastral maps, high definition satellite images, altimetry and topographic data coming from the Differential GPS and radar data. In this way all the information, from digital and paper cartography, can be used to draw as much details as possible, which are then organised in several layers in the GIS of the area, which is updated regularly with the data coming from the field survey, the soundings, the geophysical survey, the geomorphologic analysis and the old information on previous excavations and surveys. In this way the GIS can be used for very different purposes, such as to locate the archaeological finds and remains on the cadastral plots, as well as for a geological or environmental study of the area, or for a reconstruction of the ancient landscape assessment in different periods. Obviously a homogeneous methodology, both in the field survey and in the registration of the data, is extremely important for a complete view and exhaustive study of the territory. Therefore the database, which has been developed in access, both for the survey and for the soundings, as in other projects of our team, is based on several registration forms, working on the bases of cross links, which are then imported into the GIS project (fig.1), collecting a large amount of data and of multidisciplinary information.

The field survey is based on a combination of judgemental and intensive survey, the latter with small teams of peoples walking at a regular distance, in order to maintain a homogeneous sampling strategy. However, in steep or very hilly areas, where it is difficult to maintain peoples walking in parallel lines, the DGPS are used to stabilize the sampling strategy. Each surveyed field is therefore recorded, both in case of positive and negative finds, in a field registration form, which is then linked with further registration forms, of scatter site, structure, geo-morphological unit, find and so on. The archaeological sites are then positioned, with the DGPS, on 3D bases, and the last step is the 3D modelling of a DEM (Digital Elevation model) and a DTM (Digital Terrain Model) of the territory for a better interpretation and reconstruction of the ancient landscape assessment and for mapping in a proper way the possible ancient passages, road network and natural crossing point.

The integration of the laser scanning for the monumental structures, of the plans made with the IS robotised Total Station, the data from the DGPS positioning, with the plans and drawings of the excavation can allow a reorganisation of the general plan of the sites. This step has already been started for the excavation of Pyrgos, thanks to our collaboration in the project PY.R.A.ME and a new plan of the site is now in progress with the post processing of the data coming from our seasons in 2010 and beginning 2011. Moreover, the use of aerial photo, taken by kite (with PCavet system for stabilising the camera) and drone (exacopter), gives the possibility to organise both hortho-photo-plan and stereoscopic views of the site, with the hortho-rectification in post processing. In this way, the maps and the hortho-photos of the sites can be used as base for an 'intrasite GIS' documentation. In the season September 2010 a new mapping of the site of Pyrgos with IS total station has been completed and also the scanning of crucial points of the excavation has been recorded. The data are now giving a new version of the plan of the site, but also plans of the chronological phases of some of the monuments and a base for projecting new excavations, restorations and valorisation of the site. Moreover, the seasons 2011 (February, May and September-October) and 2012 (February and May) have mostly been dedicated to the survey of the territory and to the mapping of several new sites, which have also been surveyed with geophysical prospection.

One of the layer of the GIS, in fact, is already collecting the data coming from the geophysical survey. The methodologies used for these non invasive investigations consists in the use of three methods, which are quite well known and largely used in archaeological contexts, such as geo-radar, magnetometer / gradiometer and georesistivimeter. The choice of the method for each plot is made on the basis of the geo-morphology of the area, and in case of particularly interesting areas or results, a second method is combined for a better interpretation of the resulting anomalies attesting the probable presence of archaeological remains. In our 2011 and 2012 seasons we have mainly used the magnetometer/gradiometer method, employing GEM –GSM 19 Magnetometer, with double sensor with vertical setting configuration (Magnetometer+Gradiometer) working in combination with a DGPS system for the precise positioning of the plots and of the anomalies. The results have been elaborated with Surfer 8 and then filtered and imported into ArcMap 9.3, for locating precisely the anomalies and also for interpreting the anomalies in the wider view of their contexts. During this step of the project a geodatabase with magnetometric information of the anomalies has been organised, in order to create the basis for different levels of results and for comparisons with further results coming from future other analysis. The different levels of the geoarchaeological analysis, the GIS of the field surveys, the positioning of remains and so on, are elaborated in the same GIS format and project, but treated as different levels for avoiding any possibility of interference of the results and at the same time to favourite a multidisciplinary approach.

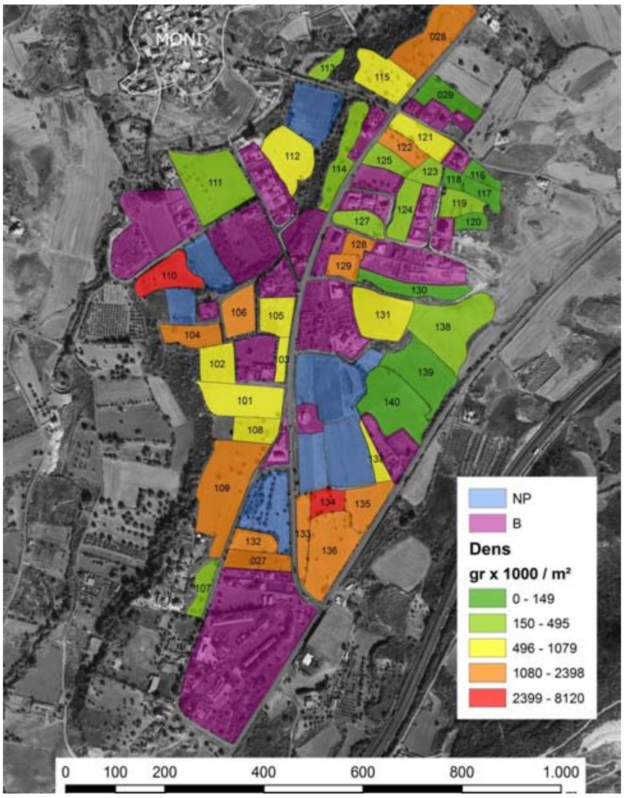


Figure 1: View of the GIS showing the density of the finds from the intensive field survey in the transect of Moni

1.3 Preliminary results

The territory of MPM Project (fig.2) is morphologically very interesting for its richness in geological and mineral resources, hydrographical network, geo-morphological units and topographic districts, giving place in antiquity to very differentiated typologies of settlements, exploitation of the resources, territorial organisations and relationships among different topographic units.

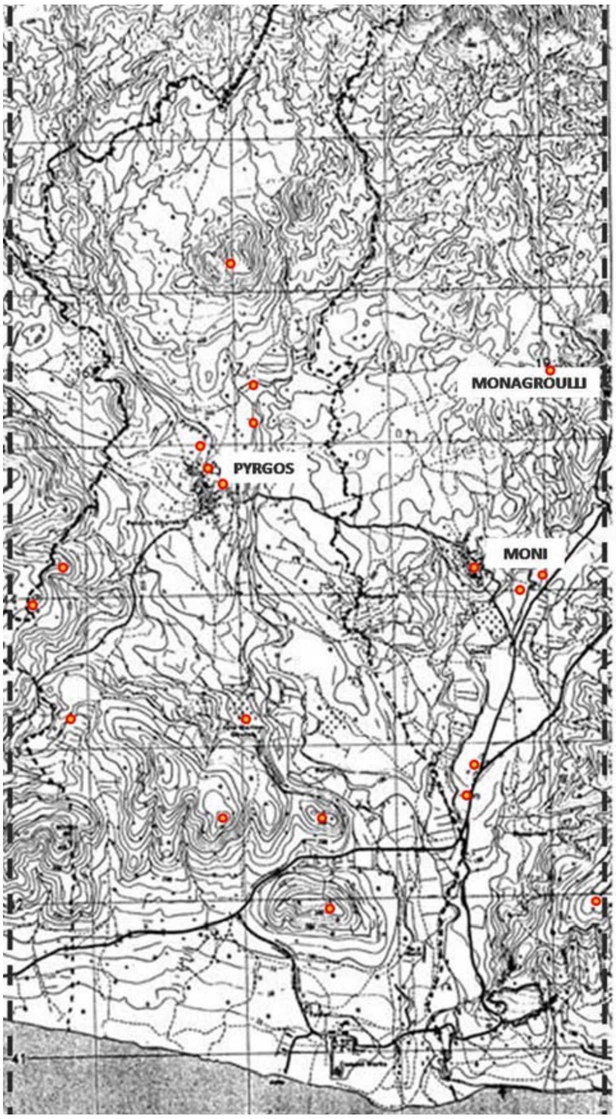


Figure 2: The area of the project with the indication of the sensible areas with possible sites, which are at the moment under investigation with non invasive geological prospection

The landscape is changing a lot, from the mountainous area just at the back of Monagroulli and Mazokabos, to the hilly area of the Pyrgos valley, to the plain river terraces of the Moni valley, to the rocky and steep coasts of the area of the geological cliff just to the west of Agios Georgios Alamanos, to the flat beaches at the mouth of the rivers. Especially for this reason a team of geologists and geo-archaeologists is working on mapping the topographic and geo-morphological units (TU and GMU), in order to have a complete view of the territory and also the geological situation in detail. At the moment the recording of the data for this aspect has been completed, and the team is now working in post processing in the interpretation of the data and in the delimitation of the TU and GMU which will be of great help then for the interpretation of the data coming from the archaeological surveys.

Two archaeological teams, composed by archaeologists, surveyors and topographers, are working in the intensive and in the judgemental surveys of the area, with about 12 sites already mapped, about 6 of them also surveyed with geophysical methods, and in 5 cases presenting also structures which have been documented and their study is still in progress.

A team of 4 scuba divers has also surveyed the coasts of this transect, in order to document more completely the geo-morphological units, giving already interesting results locating the main points geologically adapt for ancient docking, which is going to be an important information when the picture of sites and settlements is clear, to understand their relationship with possible docks and coasting trade.

Because of the richness of minerals, especially copper and iron, also a team of speleologist and archeo-speleologist is working in the survey of old mines, often showing a long frequentation, and among many surveyed mines, caves and quarries, already a possible ancient copper mine along the Pyrgos valley has already been mapped and documented, showing a possible exploitation from classical to medieval periods and then abandoned, probably because the mineral vein was finishing, and richer veins were found few kilometres to the north.

The strong difference between the Pyrgos and the Moni valleys, have probably determined a completely different organization of the settlements and exploitation of the soil and resources. The Pyrgos river was flowing, in antiquity with a stronger pressure and a wider water capacity, but on very irregular bases, causing a morphology of the valley typical of a canyon / wady. This feature was certainly largely exploited in antiquity, because an interesting structure along the river has been found, documented and analysed, showing about three phases of use, since the Roman period and with Medieval and Lusignan restorations and partial re-buildings, which was used as bridge-dam, probably for creating in specific periods an artificial small ideographic basin, both for irrigating the small agricultural fields around, but mainly for serving the area of mining, located just to the north of the structure. Moreover, the area of the bridge-dam, which is known with the evocative place name of Dimmata, and of the small copper mine, is very rich in Hellenistic and roman pottery, suggesting that a possible Hellenistic-Roman settlement was there located, in close relationship with the exploitation of the mines and of the presence of abundant and drainable water.

The Moni river valley, contrariwise, is and was characterised by wide alluvial plain and fertile river terraces, which are and were largely exploited for agriculture, mainly oil and wine production, as the large quantity of amphora and dolia/pithoi shards coming from the survey have attested. In this area several interesting sites have been surveyed and analysed with geophysical methods, and already at this preliminary stage of the research is possible to locate some farms and rural settlements in the area, dating to the Hellenistic and Roman periods.

Another interesting site has been surveyed in the area of Agia Marina, just 2 kilometres to the south west of Pyrgos, presenting a large quantity of finds, already at the preliminary surveys, and attesting a frequentation from the Middle Bronze Age to the Medieval period, with a possible long metallurgic activity in the area.

The already large quantity of data and finds is, during the winter seasons, post processed and more closely analysed. In the following paragraphs the protocols of the study of the pottery, both on archaeological and archaeometric bases, are presented, in order to give an idea of the work, which is still in progress, and also for looking for parallels and collaboration with other teams working in Cyprus on common bases.

2. ARCHAEOMETRIC PROTOCOLS AND ANALYSIS ON POTTERY FINDS (M.C.M.)

2.1 Protocols and analysis

Looking at the huge amount of pottery fragments, collected during our surveys, it seems to be conceivable that the economic vocation of these sites was based on the production and export of local products, importing consequently materials and different products from Mediterranean lands, especially for the period between the Middle Bronze Age and the Late Medieval Age. The pottery finds dating to these period, seem to confirm a large production, mainly agrarian, with numerous *amphorae* and other containers, certainly related with the local oil, wine and famous perfumes production and their export outside Cyprus.
The study of these pottery finds has been based on common protocols for our projects, both in Cyprus and in other areas of the Mediterranean basin, especially in Libya (Antonelli-Menozzi, forthcoming), with a sampling of the fabrics with a microscope scanning in field as first step, in order to have a preliminary digital microscope analysis as base to collect the samples. A second step, still *in situ*, has been dedicated to the geo-morphological analysis of the territory, with sampling of the local clays, soils and sediments, specifically taken by geologists, in order to have possible reference samples for the local productions. Then, a third step, in laboratory, it has been based on EDX and TSA analysis, for a further grouping of the fabrics. Only few specific samples of fabric are then chosen for further investigations, such as SEM analysis, with a fourth step limited to problematic or particular fabrics.

The samples of fabrics from Cyprus, dating between a huge chronological span from Middle Bronze Age until the Late Medieval period, which have been collected counts more than 100 shards during the first step, and then we are grouping them, during the second step, in main categories. At the moment it is possible to assert the presence of a high percentage of local productions and lower percentages of imported pottery, mainly from Near East and Mycenaean and Aegean world, during the Bronze Age, and principally from Northern Africa in the Roman period. Moreover, because the *amphorae* and other containers were exported for their contents, we are also trying to analyze the possible remains of the contents with gas-chromatography/mass-spectrometry tests, which are still in progress and need some more samples.
The huge amount of data, coming especially from surveys is then collected into a GIS project of the area, which is a useful geo-referenced archive (on ArcMap/ArcGis bases) with a large amount of information organised in different interacting layers. The data coming from the analysis and study of the pottery is constituting specific layers concerning the archaeometrical data, the distribution of the fabrics and the location of the main areas with specific clays, fine soils and sediments, in order to have also the main provenances of finds, fabrics and raw materials and then compare them also with the layers concerning the possible sites with agricultural productions, marked on the bases of the distribution of oil and wine presses, mills, organised storerooms, paleo-botanic analysis, amphorae and *pithoi* shards and so on.

2.2 Sampling of fabrics, microscope scanning and cluster analysis

Petrological approaches were applied to the identification and characterization of local and imported ware fabrics, placing them within the geological context of Cyprus. A combined of petrological and technological approach is the best application, since fine pottery and amphorae cannot be studied only on the basis of shape. The different composition from the range of fabrics will allow to identify and distinguish local fabrics from imported wares. The local and imported ware are examined in terms of technology (clay exploitation and manipulation) and provide to show characteristics and differences between pottery groups represented in the region. Typological and technological similarities will be studied in a geographical distribution of local and traded pottery circulation.

As researches stand now, we have carried out the microscope scanning of more than 100 different fabrics (the huge number of fabrics is due to the long chronological period in exam) and the geo-morphological analysis of the territory, both *in situ*. The preliminary results demonstrate a prevalence of local pottery production, almost certainly linked to the significant agricultural production and roman farms, suggested during the surveys by numerous amphorae fragments.
Obviously the fabrics already selected, are going to be grouped carefully on the basis of a series of features, that is: composition, association with specific typologies and forms, technologies employed in their production.

Because the step of grouping the fabric in main types and choosing the sample for further analysis is a quite delicate step of the archaeometrical protocol, we have established that this phase has to be carefully monitored both by a geologist expert in archaeometry and archaeologists aware of the need both of the archaeometric and archaeological approach ti the study of the pottery.

Hereafter, we represent same microscope scanning images of samples of the main wares and their geo-morphological composition:

COARSEWARE

CG1 – irregular, degreasing, igneus rock, heterometric, clastic, rare calcine, sub-rounded volcanic fine-grained sand, C section, pseudofluidic structure; 20 mm

AMPHORA

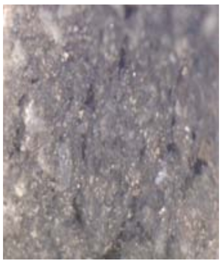
A5 – irregular, degreasing, fine-mid-grained sand, igneus rock, sedimentary rock, section EC, isotropic lumpy structure, low sorting; 12 mm

FINEWARE

CD4 – regular, topped, cleaned degreasing, fine-grained sand, until smooth, ECI section (E-I topped) pseudofluidic dune structure; 7 mm

RED POLISHED

CRP1 – regular, turned, smooth, topped, degreasing, calcine and igneus rock, mid-coarse sand, low smooth, section ESCSI, pseudofluidic structure; 18 mm
regolare tornita lisciata ingobbiata, degrassante calcinelli e rocce ignee, sabbie medie e grossolane scarso sortito, sezione ESCSI, struttura pseudofluidale, spessore 18 mm



FINEWARE

D4 – irregular, degreasing igneus rock, limestone, mid-coarse sand, well rounded grain, bad smooth, ECI section, pseudofluidic grain structure; 13 mm

COARSEWARE

CR2 – regular, turned, inner glazed, degreasing, cleaned, calcine, igneus rock, chamotte, fine sand, well smooth, ECIV section (V= glaze), regular isotropic structure; mm. 5.

The first step of cluster analysis has identified some homogeneous typological groups, as well as Red Polished for the Bronze Age; miniature fictile for the Archaic Period; amphorae and fine wares for the Roman Age; glazed pottery for the Medieval Period, and so on. We have started a diachronic research on the Red Polished found during the survey in the area, dividing into six principal subgroups, according to typological and topped characteristics: Fine Polished; Black Topped; Metallic Ware; Red Painted; Coarse Polished; Uncertain. Completed the research of the typological studies and of the shapes, the next step will be the specific analysis.

The wares from MPM project demonstrate the potential of the study of distribution and economic interaction. The imported wares attest to an interregional trade in specialized vessels with fabrics and forms adapted for particular functions, and significant trading networks extending across the Eastern Mediterranean and Aegean Sea and linking Cyprus and Northern Africa and Western Mediterranean. This important research provide an interesting source of evidences of the ancient technology and economy in Cyprus and the wider Mediterranean trade networks from the Mid Bronze Age to the Medieval Period.

2.3 Further archaeometric analysis

Further archaeometric analysis will be carried out in collaboration with the geologist Silvano Agostini, member of the Geological and Paleontological Service of the Superintendence for Archaeological Heritage of Abruzzo- Italy (MIBAC) and geologist and archaeologist of CAAM.
Thin sections and chemical analysis (microscopy, XRD) will be carried out on samples taken from some pottery finds. Data relative to the composition (MPC), technology aspects considered as a set both cultural and environmental combination (TCA), will be compared and tabulated in a standard database, according to the guidelines of an analytical protocol developed by the Geological and Palaeontological Service. A statistical analysis (through hierarchical clustering: graphs should show all the variables, single and complete bond/euclidean distances; all the variables, single and complete bond/percentage differences; only paste variable, single and complete bond/euclidean distances; only paste variables, single and complete bond / percentage differences) will be carried out on the dataset of samples to distinguish the different pastes and the production technology. For this analysis, thirty-five variables at least will be considered: minerals, fragments of sedimentary and igneous rocks, chamotte, fossils, "pedorelitti" if present, and other such petro-fabric typology, percentage and size of temper, paste typology (MPC-TCA), colour/colours on thin section with parallel nichols view interior and exterior finishing surfaces of vessels, etc. The results of the study should highlight the following features: the minerals and petrographic components will identify the main groups and single sample; the difference between the types of each group will be due to production technology and for the different degree of stylistic refinements. The temper volume percentage ranged between 5% to 30% in coarse paste mixes of the main groups. The sample marked in imported amphorae and other containers (for instance from Northern Africa or Near East) will show with a ceramic paste very different from the other samples. The preliminary results of this investigation are promising enough to encourage future research with acquisition of new and different analytical data (XRD, X-ray fluorescence,) from a larger number of samples from other archaeological sites in the Cypriot area.

3. CONCLUSIONS (M.C.M. & O.M.)

This paper gives a short account on the main findings of pottery and illustrates the preliminary results with the aim of further enhancement and completion of knowledge of populations that inhabited this region from the Middle Bronze Age to the Medieval Period.

The study focuses on Bronze Age, Archaic, Classical and Medieval wares from the survey in the Pyrgos region, in Southern Mid Cyprus. A *terminus ante quem* for the pottery from the sites is provided by the most ancient human settlement presents just in Pyrgos-Mavroraki, the earliest excavated context not included in this study and dating from the Mid and Late Bronze Age. The main important approach to the pottery finds during our survey is based on the combination of technological and petrological methods, applied to identification and characterization of local and imported ware fabrics.

The preliminary results demonstrate a prevalence of local pottery production, almost certainly linked to the significant agricultural produce and roman farms, highlighted during surveys and numerous amphorae fragments.

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THE POLYCHROME SINOPIA OF ROMAN MOSAIC AT LOD (ISRAEL): PIGMENTS CHARACTERIZATION AND MICROSTRATIGRAPHIC STUDY

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KEY WORDS: Mosaic, Policrome Sinopia, Pigment analysis, Microstratigraphy, Painting techniques, Roman Times

ABSTRACT:

This paper presents the results of the archaeometric study on the pigments and the painting techniques used to produce the polichrome sinopia found under the *tesserae* of the Roman mosaic at Lod (Israel). The red, yellow, green and black paints, laying on the *sovranucleus* of the preparation mortar under the mosaic, were studied by polarised light microscopy on disperse pigments (PLM), reflected light microscopy (RLM), scanning electron microscopy (SEM) and X-ray powder diffraction (XRPD). The palette comprises red and yellow ochre, cinnabar, green earth and carbon black. The microstratigraphic analysis shows the presence of a carbonation layer including the pigment particles on the top of the mortars, indicating that the pigments were laid on a fresh mortar, according to a *fresco* technique.

1. INTRODUCTION

The Roman mosaic from Lod (formerly Lydda, 20 km south-east Tel Aviv, Israel) is one of the most beautiful and famous pavements of the Roman Empire. It was fortuitously discovered in 1996 and excavated by the Israel Antiquities Authority (Avissar, 1998).
The mosaic, representing both real and mythological animals (Figure 1), is constituted by 3 very well preserved floors, for a total area of 150 m^2. It is dated to about 300 AD and probably belongs to a large and important Roman villa (Haddad and Avissar, 2003). The ichnography of the mosaic suggests that the owner of the villa was a rich merchant who probably reached his position thanks to maritime trade.
After the detachment performed in the 2009 by the Art Conservation Department of the Israel Antiquities Authority, a extraordinary polychrome sinopia (an underpainting) was discovered under one of the most evocative scene of the mosaic, the marine representation of fishes and vessels (Figure 2).
It worth noting that the term sinopia normally refers to an underpainting realised using a red ochre, originally from Sinop on the Black Sea (Turkey), to make a preparation draw for a fresco, generally executed on the finer mortar layer, the *arriccio*. This technique was largely used until the sixteen century, when it was gradually substituted by other preparation techniques, such as *graffito* and pounce. The adoption of a sinopia in the production of a mosaic was typical of the Greek word and less frequently used in the Roman mosaics. Besides, the Greek artisans used only one pigment to draw the sketch on which apply the *tesserae* (mainly red ochre or carbon black), and polychrome sinopiae have never been attested before. For all these reasons, the finding of a polychrome sinopia, a red, green, yellow and black paint under the marine scene of the mosaic from Lod is absolutely unique in the history of art.
This study mainly aims to characterize the pigments adopted to prepare the rare polychrome sinopia discovered under the extraordinary marine-scene panel of the Lod mosaic, as well as to define the microstratigraphy of the paint.

Figure 1. The Lod mosaic

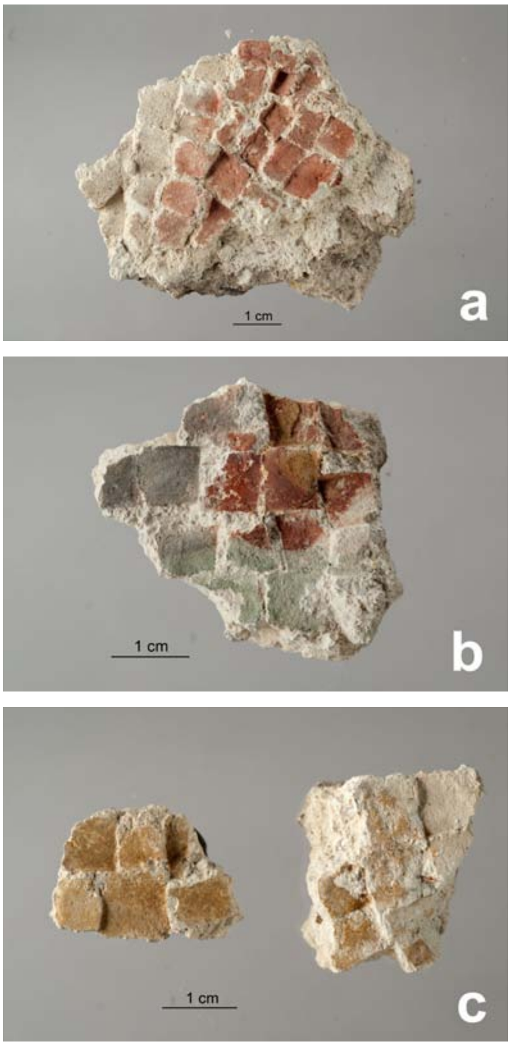
* Corresponding author.

Figure 2. Detail of the marine-scene panel

These will supply information on the painting technique adopted to paint the sketch, and in particular to verify whether it was realised as a fresco. Indeed macroscopic analysis of the mortar shows the presence of joints in the preparation layer (*sovranucleus*), indicating daily applications of mortar (*giornate*), and suggesting the use of this technique.
All these aspects will indicate the technological knowledge owned by the masters who made the mosaic.

2. MATERIALS AND METHODS

A set of 8 fragments of *sovranucleus* bearing four different colours (red, yellow, green, black) was selected for this study (Figure 3).



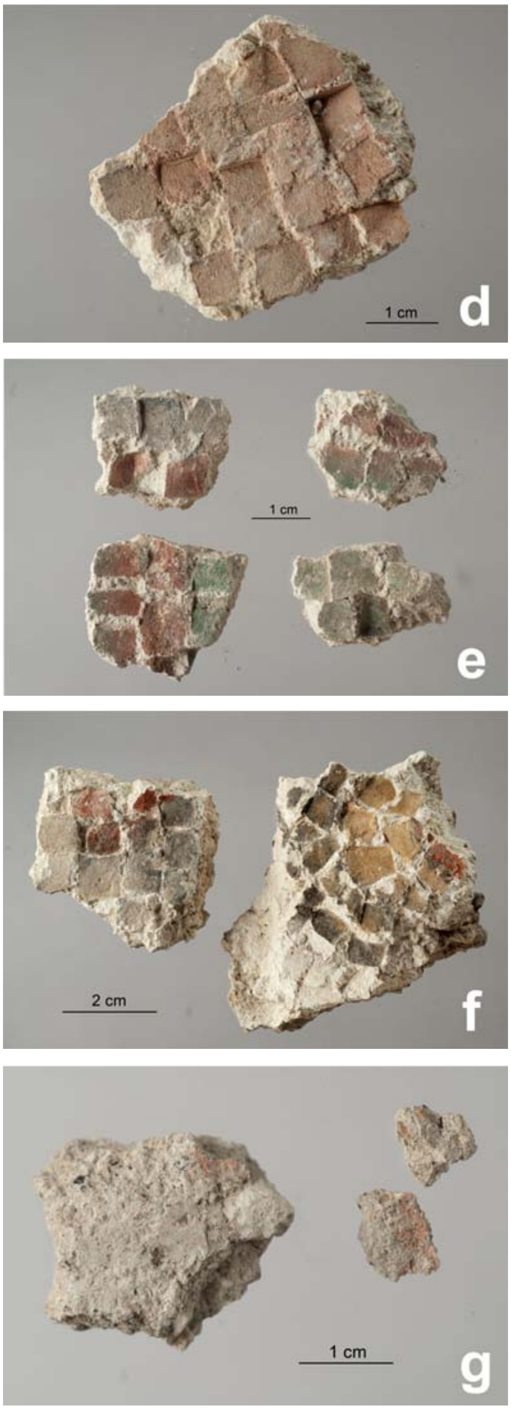


Figure 3. Hand specimens of the painted *sovranucleus*:
a) sample 1- red; b) sample 2 - red, yellow, green and black; c) sample 3 - yellow; d) sample 4 - pale red; e) sample 5 - red, green and black; f) sample 6 (on the left) - red and black; and 7 (on the right) - red, yellow and black; g) sample 8 - trace of red pigment in a small track

Macroscopic observations indicates the classical stratigraphy of the Roman mosaics, formed by a thick preparation layer of gravel and clay used to level the ground roughness and to form a solid base for the floor, covered by a *rudus*, a layer of rough mortar, in turn covered by a *sovranucleus*, a layer of finer mortar on which the sinopia was painted, and the *tesserae* (Figure 4).

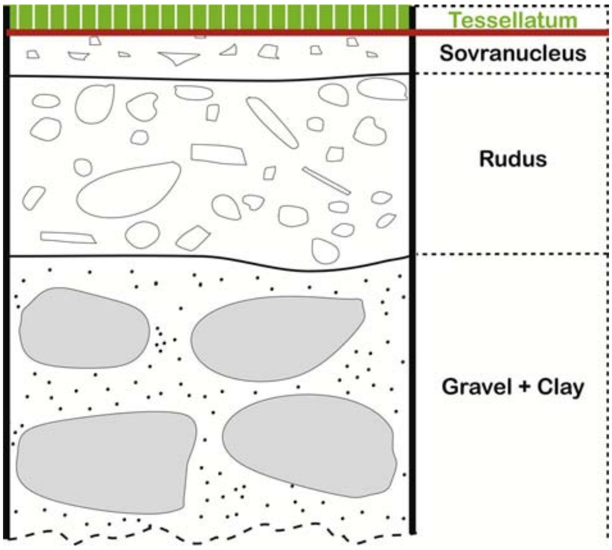


Figure 4. Stratigraphy of the Lod mosaic floor. The red line shows the position of the sinopia painting

N.	Sample	PLM	RLM	SEM-EDS	XRPD
1	1R	X	X	X	
2	2R	X	X	X	X
3	2G	X	X	X	
4	2Y	X	X	X	
5	2B	X	X	X	
6	3Y	X	X	X	X
7	4R	X	X	X	
8	5R	X	X	X	
9	5B	X	X	X	
10	5G	X	X	X	X
11	6R	X	X	X	
12	6B	X	X	X	
13	7R	X	X	X	
14	7Y	X	X	X	
15	7B	X	X	X	
16	8R	X			

Table 1. List of samples and analyses performed on them. The sample labels are composed as follow: number.letter, indicating the number of sample (according to figure 3) and the colour of the paint (R: red, G: green, Y: yellow, B: black), respectively

Samples were studied according to a multianalytical approach, consisting on the combination of microscopic, microstratigraphic, microchemical and mineralogical analysis (Table 1). More in detail, all the fragments were studied by:
i) optical microscopy in reflected light (RLM) on cross sections, in order to accurately define the microstratigraphy;
ii) optical microscopy in transmitted light on pigment dispersion (PLM), to identify the type of pigments;
iii) scanning electron microscopy coupled with an energy dispersive spectrometer (SEM-EDS) on cross sections for the identification of the pigments and to verify the microstratigraphy;
iv) X-ray powder diffraction (XRPD) to define the mineralogical composition of the pigments.

3. RESULTS AND DISCUSSION

3.1 Microstratigraphy

Most of the analyzed samples are constituted by a very simple microstratigraphy, such as that shown in Figure 5a, made by the following sequence of layers:
A: white plaster layer (*sovranucleus*);
B: painting layer.

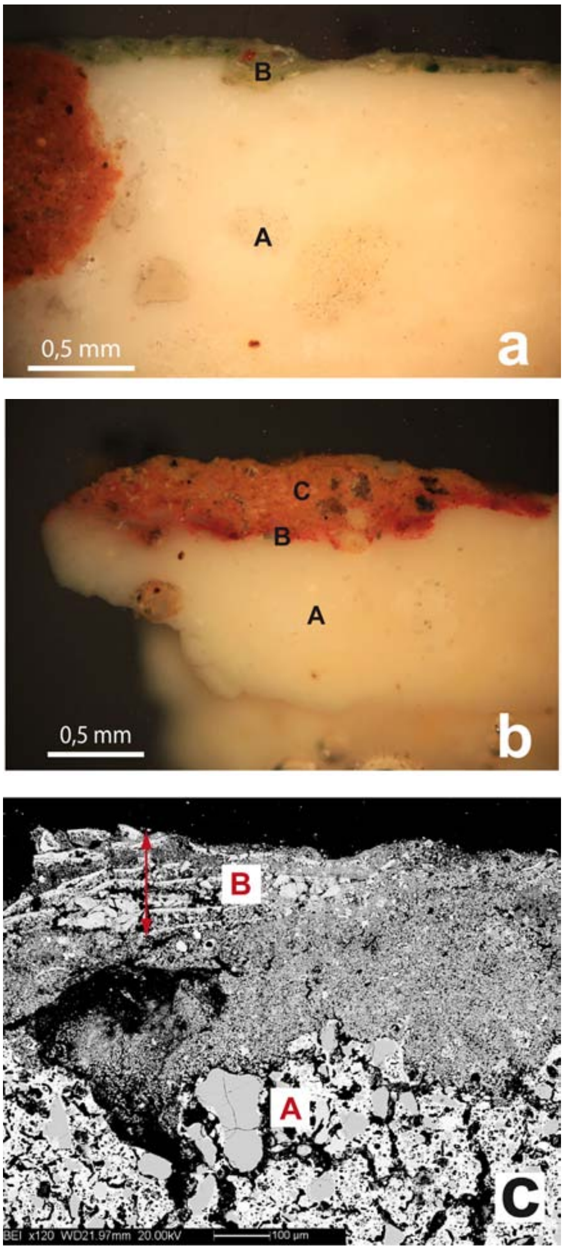


Figure 5. a) RLM micrograph of the cross section of sample 2G with only two layers (A: *sovranucleus*; B: painting); b) RLM micrograph of the cross section of sample 2Y, where two painting layer are present (layer B and C); c) SEM-BSE image of sample 5G with several carbonation layers on the surface

Among the studied samples, some exceptions to this simple stratigraphy were find. The first one is the sample 2Y, where two painted layers are present. This anomaly is due to a partial overlapping of a yellow area (layer C) on a red one (layer B) (Figure 5b).

Another exception is the sample 5G, which shows a thicker green layer, the back scattered electron image (SEM-BSE) of which shows that it is formed by several layers similar in composition (Figure 5c). Moreover, the presence of at least two carbonation layers (arrows in Figure 5c) indicates that the artist waited several hours between one brushstroke and another, during which the mortar underwent a gradual hardening.

3.2 Painting layers

SEM analysis on the paintings shows a thin white layer on the surface of each sample (Figure 6), incorporating the pigment particles. This, as described in Piovesan et al. (2012), is the result of the carbonation process occurred on the surface of a mortar during the hardening, and clearly indicating that the painting was realized following the fresco technique. Therefore the particles of pigments were spread on the fresh mortar of the *sovranucleus* only diluted in water.

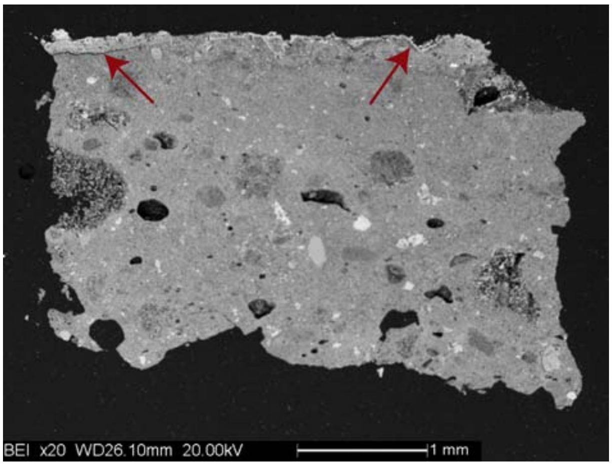


Figure 6. SEM-BSE image of sample 4R: the red arrows show the typical carbonation layer at the surface, including the pigment particles

3.3 Pigments

PLM, SEM-EDS and XRPD analyses indicated that each colour of the sinopia is composed by a single pigments, with the exception of the red one, and that 5 different pigments were identified.

The red colours are mainly due to the use of red ochre. This pigment is mostly formed by hematite, which is characterised at the PLM by interference colours typically masked by the strong body colour (Figure 7a). The size of these particles ranges between around 50 and 200 m.

In some cases the red colour of the sinopia was obtained using, in addition to the red ochre, a very fine-grained pigment, few microns in size, often occurring in dense aggregates at the sample surface (white particles in the SEM-BSE images of Figure 8a), the microchemical composition of which is very high in Hg, indicating that is formed by cinnabar (Figure 8b). This pigment was not recognized under PLM and RLM, probably for the extremely small dimension of the particles.

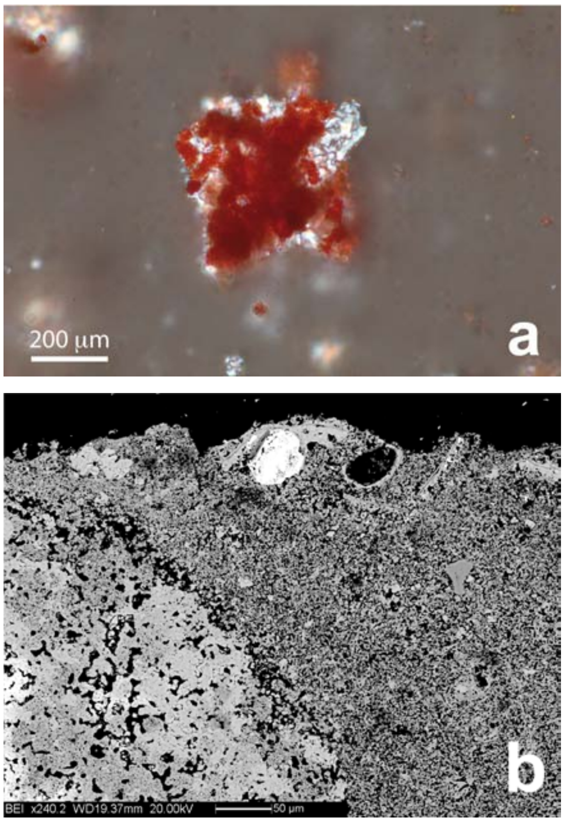


Figure 7. a) PLM micrograph of red ochre particles (plain polars); b) SEM-BSE image showing sparkling white particles at the sample surface, very rich in Fe in the EDS analysis.

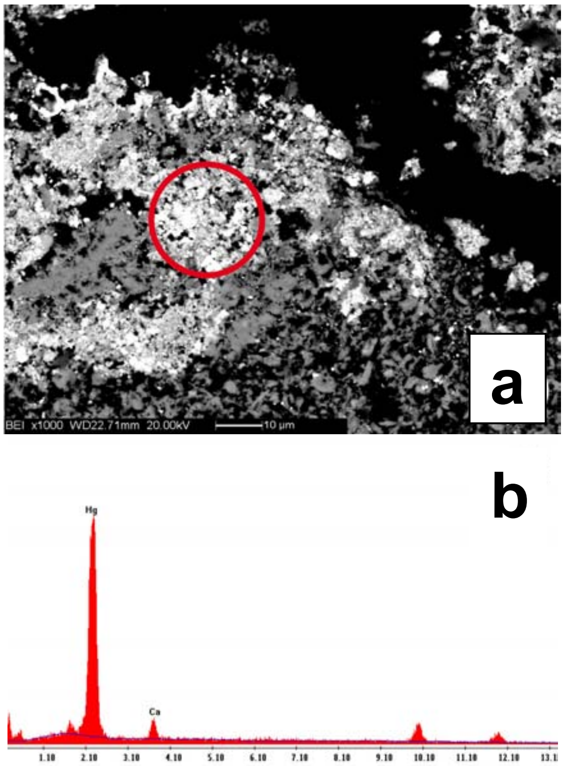


Figure 8. a) SEM-BSE image of very fine particles (in the white circle) showing high contents of Hg (b)

The yellow colour was obtained using a yellow ochre, mainly composed by goethite (Figure 9), characterised, when observed under PLM in pigment dispersion, by interference colours typically masked by the strong body colour (Figure 9a).

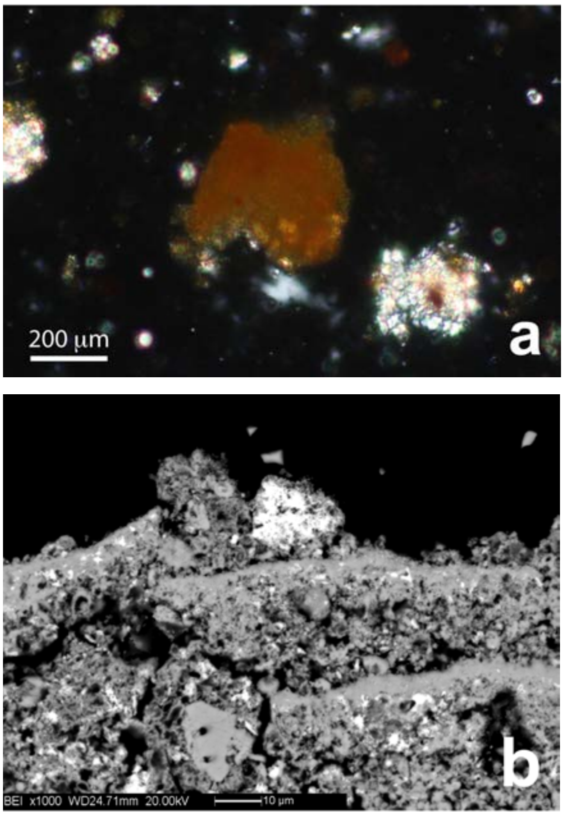


Figure 9. a) PLM micrograph of yellow ochre particles (cross polars); b) SEM-BSE image showing sparkling white particles at the sample surface, very rich in Fe in the EDS analysis

The green pigment is composed by green earth, formed by sub-rounded particles, some tens to hundreds microns in size (Figure 10a). This type of pigment may be composed by either glauconite or celadonite. The distinction among these phases is generally difficult since both have very similar XRPD patters, with peaks at the same 2Theta values (Figure 10b). The occurrence of micro-foraminifera shells associated with the pigment particles at the sample surface, as shown in the SEM-BSE images (Figure 10c), indicates that the green earth used for the sinopia of the Lod mosaic derives from seashore deposits, and it is formed by glauconite.

Finally, the black colour was obtained using a carbon black pigment, in which the carbon particles show the characteristic black and opaque colour and occur with irregular shape (Figure 11a). In many cases traces of the cellular structure are well preserved (Figure 11b at the centre). Moreover, this pigment is associated to the presence of spheritical particles of glass, showing degassing bubbles (Figure 11b), probably produced for the melting of soil particles during the combustion of vegetal remains (wood or chaff) for obtaining the carbon black.

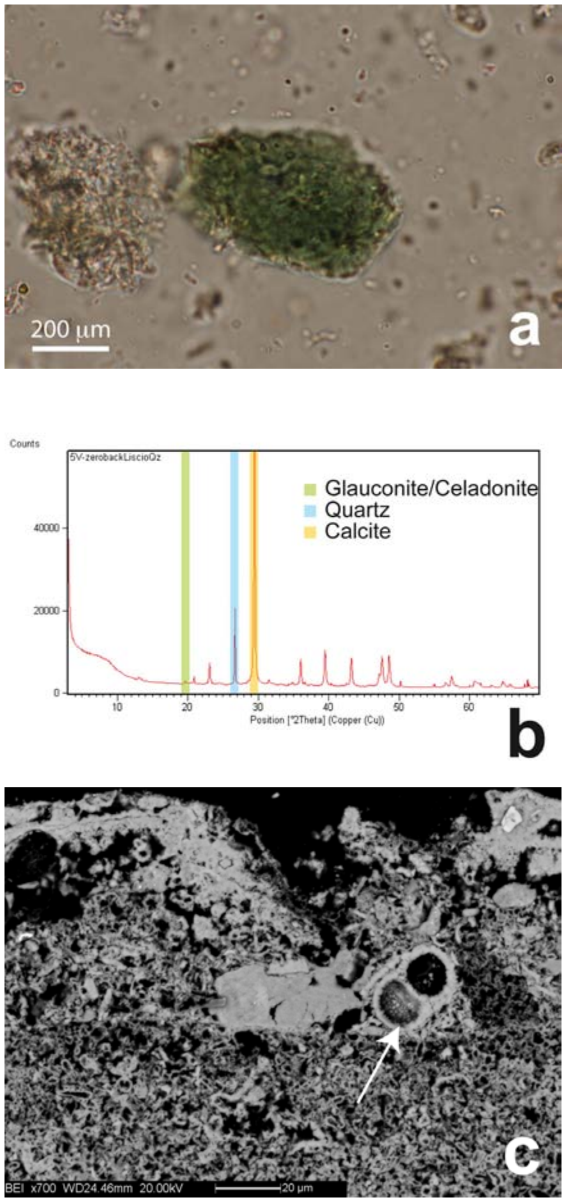


Figure 10. a) PLM micrograph of pale green rounded particles (plain polars); b) XRPD pattern; c) SEM-BSE image of green earth particles associated with shells of micro-foraminifera on the sample surface suggesting that the green earth comes from seashore deposits and is formed by glauconite

4. CONCLUSIONS

The results obtained by this multianalytical study of the polychrome sinopia discovered under the marine scene of the Lod mosaic show a composition of the pigments used and a structure more complex than expected.

Starting from the colour palette, the use of five different pigments indicates the need of the artists who realised the mosaic to have a very detail paint to use as a base when executing the mosaic itself. This would respond to the commissioner requirement to have a very high quality mosaic, probably representing his main activities. The pigments used, and in particular the red and yellow ochre, the green earth and the carbon black, are very common pigments, easily available.

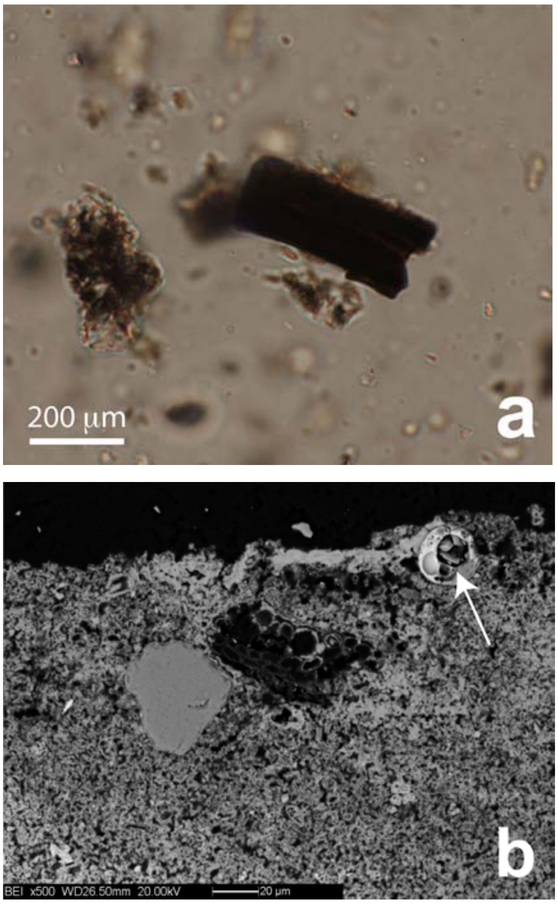


Figure 11. PLM micrograph of black and opaque particle showing regular shape and traces of cellular structure (plain polars); b) SEM-BSE images showing well preserved cellular structure and glass particles (white arrow) probably derived from the combustion process

The cinnabar represent an important exception, since it is an unusual pigment to produce a draw that would be covered by the mosaic *tesserae*, due to its high value and cost. Although found occasionally, the occurrence of the cinnabar indicates that the artist who realised the sinopia had important skill in the painting decorations, so that he has this precious pigment among his colour palette.

The presence of a carbonation layer on the top of samples, including the pigment particles, indicates that the pigments were laid on a fresh mortar, according to a fresco paint technique.

All these pieces of information indicate that the extraordinary and unique, for that period, polychrome sinopia found under the Lod mosaic attests the wealth of the commissioner as well as his desire of realising a superb and unique piece of art probably to celebrate his success in the marine trades.

During the conservation of the mosaic three panels with sinopia were successfully divided from the backing of the mosaic. The extremely complicated operation of detaching the *sopranucleus* from the lime bed without to damage the paint layer was accomplished in the laboratory. The panels of painted plaster were conserved using the techniques for wall paintings conservation according to the data from this research. In the light of the consideration about the painting technique the conservation problems were resolved using the knowledge for frescoes conservation and consolidation. The exhibition panels were executed using the systems for wall painting conservation: honeycomb panels with sacrificial layer with the painted plaster applied using lime mortar.

The whole process of conservation of the Lod mosaic can be followed on www.lodmosaic.org. In this moment part of the Lod mosaic and one of the panels with sinopia are exposed at Columbus MUseum of Art, Columbus, Ohio, USA. The entire mosaic with all the other discoveries from the archaeological site will be exposed at the Shelby White and Leon Levy Archaeological Centre (under construction) in the city of Lod, Israel.

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EASING THE CREATION OF MAPPINGS BETWEEN METADATA FORMATS

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KEY WORDS: metadata, mapping, conversion, crosswalk, formats, archives, museums, configuration, tool, web service

ABSTRACT:

Being able to exchange metadata is the key to ensuring access to collections, establishing interoperability among collections, and between different types of cultural heritage institutions, such as across libraries, museums and audiovisual archives. Motivated by two use cases, one for audiovisual archives and one for museums and general archives, we present an approach for automating mapping between different metadata formats. The mapping approach uses an intermediate ontology and formalises the relations to each of the metadata formats supported. An intuitive web-based configuration user interface is provided in order to build and customise mappings. Based on the two use cases, we discuss two ways of applying the mapping approach: as a web service, which can be included in processes of an audiovisual archive's preservation system and integrating of the generated mapping instructions into collection management applications for museums and archives. The proposed approach reduces the effort for defining metadata conversions. It thus allows overcoming interoperability issues between cultural heritage institutions and facilitates content provision to portals like Europeana and Archives Portal Europe.

1. INTRODUCTION

Preserving cultural heritage does not only require ensuring the integrity of the objects to be preserved, but also includes making them accessible and usable, i.e. providing technologies for long-term access and use in changing contexts. Being able to exchange metadata is the key to ensuring access to collections, establishing interoperability among collections, and between different types of cultural heritage institutions, such as across libraries, museums and audiovisual archives. Metadata exchange is often hindered by the diversity of metadata formats and standards that exist in the different communities. Thus metadata interoperability needs to be established between the different parties involved.

The problem of metadata interoperability exists on two levels:

On a *syntactic level*, metadata can be accessed and processed in the same syntactic format, today typically some XML format. This does not imply that all metadata are already XML, only that they can be rendered as such (with services or wrappers). On a *semantic level*, metadata can (partially) be interpreted within the same semantic frame of reference. Meaning of metadata of one institution (often coded in in-house metadata vocabularies) needs to be linked with metadata from another institution. Thus, it requires alignment of archive vocabularies, which might be incomplete as vocabularies differ in scope and perspective.

Tools for metadata mapping are needed to overcome these interoperability issues. However, with n formats existing in a given environment, we need in the worst case $O(n^2)$ mappings if we go for a simple approach considering only pair-wise mappings. Chaining mappings is also not a useful approach, as due to the incompleteness of mappings transitivity of relations cannot be ensured. We thus propose an approach that uses a high-level intermediate representation, together with mapping templates on data type level, from which the code for a mapping problem between a pair of standards can be derived. This would ideally allow us to solve the problem with $O(2n)$ definitions.

The need for mapping between different metadata representations comes from diverse scenarios. They include the conversion of legacy technical metadata in preservation scenarios, access to legacy content descriptions, extracting metadata embedded in digital file headers and converting it to the data structures needed in a SIP/AIP (in OAIS terminology, see ISO 14721:2003) of a preservation system, ingest of metadata from non-/semi-professional content creators, outsourcing of annotation and access services, with possibly different data models between customer and service provider's infrastructure and content provision to Europeana (http://www.europeana.eu), Archives Portal Europe (http://www.archivesportaleurope.eu/) or similar portals.

In this paper, we analyse two specific use cases of metadata mapping: one specific to the domain of audiovisual archives, and the one targeting museums and general archives. We propose a mapping approach that starts from schemata of metadata standards or in-house metadata models, in contrast to approaches like e.g. the mapping tools of the MINT framework (Kollia I. (et al.), 2012) that start from individual metadata documents. We describe the configuration user interface for defining and customising mappings and discuss the application of the tools in the two use cases.

The rest of this paper is organised as follows. After discussing the use cases in Section 2, we describe the proposed automatic mapping approach in Section 3, and then present in Section 4 a user interface for building and configuring mappings. The application of the proposed approach in the two use cases is discussed in Section 5 and Section 6 concludes the paper.

2. USE CASES

Memory institutions (such as archives, museums, libraries and so forth) are hosting collections including very different kinds of objects and archival material. These materials are used within the context of an organisation (maybe with various departments) but are also transferred to other organisations, a variety of professionals or maybe to the interested public. Metadata – the information about these objects – differ also among the various producers and consumers.

2.1 Audiovisual archives

Both audiovisual archives acting as depository institutions for specific types of audiovisual content as well as those linked to media production organisations (e.g. public broadcasters) face the issue of interfacing with processes that have diverse requirements in terms of metadata, both in ingest and access. Digitisation has blurred the boundaries between traditional types of audiovisual media, opening new options for reusing and repurposing content. This huge amount of content can be generally accessed either via standardised and proprietary metadata formats, which are often incompatible between the parties involved. As a result, the content is often locked in within silos preventing an effective search across these sites and making it complicated to exchange rich metadata for audiovisual content.

While many of the multimedia metadata formats in use overlap in their functionality, they are at the same time dissimilar in many ways.

Coverage. Some formats aim to be domain independent while others focus on specific domains (e.g. film) or usage scenarios (e.g. broadcast metadata for consumers, such as EPG information).

Comprehensiveness. Some formats aim to provide comprehensive descriptions of multimedia content ranging from low-level features that can be extracted automatically to fine-grained semantic description of a scene, while other formats provide a simple list of general annotation properties, that only refer to the entire media item.

Complexity. Metadata formats also differ in the complexity of their description syntax. Some formats only support free text for specific properties (e.g. names of creators), while others support structured content and/or references to controlled vocabularies.

Due to the differences between the formats, mappings can only be partial in many cases, e.g. when properties do not exist in one of the formats involved in mapping. If the mapping target is a format with a strict definition that does not allow extensions, information can be lost during the mapping steps.

For allowing the exchange of data between different data models some transformation of structure of the description – the metadata mapping, we focus on – and also translation between vocabularies (a potential enhancement for the future) is needed. The mapping process itself is more intended to be an underlying activity (except content provision for public portals) of the IT-systems in use for workflows in archives which usually need not become explicitly visible to the user.

2.2 Museums and general archives

Nowadays archive and collection management systems based on information technologies are widely used and have proven to provide valuable support for the management of objects in the cultural heritage domain. Archiving of cultural data is still an important issue for museums and archives. But this is only one side of the medal.

An important fact is that the presentation of the data becomes more and more important after archiving and putting a lot of effort into the scientific preparation of the data. After several years of data entry into various databases, it is now possible and important for cultural institutions to keep track, develop and make real use of these data repositories.

As museums and archives begin to transform their data management applications into smaller and more manageable application modules, it seems likely that data management will become more and more relevant. This is already considered in the *imdas/archivis pro* software package (www.imdas.at and www.archivis.at) that was developed at JOANNEUM RESEARCH. The programme can be customised to individual user needs and can be adapted to different types of objects and collections. It supports a combination of visual representations (text, images, symbols, multimedia data, and maps) and intelligent collection management. This concept of customisation enables a flexible software solution for museums and archives and offers multiple ways of accessing, analysing and presenting the data.

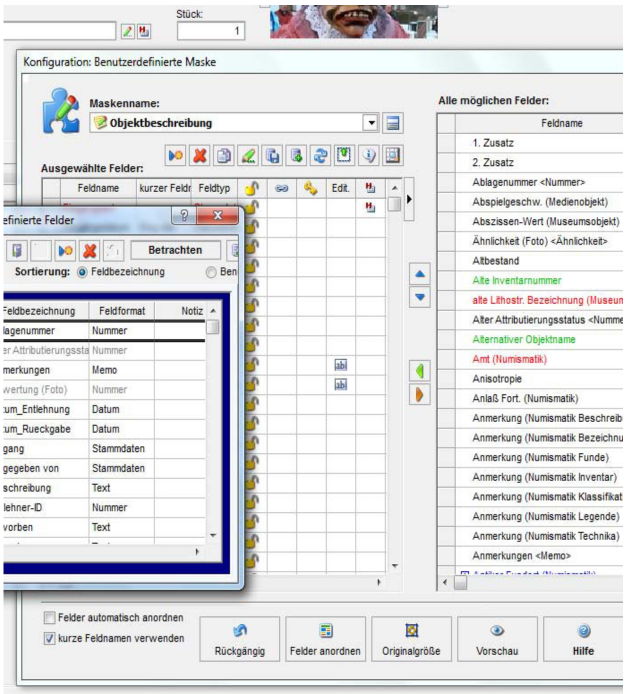

Figure 1: Customisation editor in *imdas/archivis pro*

The customisation of an information system in the domain of cultural heritage leads to individualisation also regarding metadata and metadata format. Therefore processes and systems for metadata mapping are important and necessary if data should be presented and made available via public portals like Europeana.

In order to enable different organisations with customised *imdas/archivis pro* applications to exchange data with these kind of portals it is necessary to do the mapping definition and further on the export of the data in house – without additional implementation of individual software pieces. The aim must be to have a flexible configuration tool that allows specifying the mapping between individualised (often relational) database formats and common public portals.

3. MAPPING

Our mapping approach uses a high-level intermediate representation of generic metadata elements serving as a hub for mappings between metadata formats. Therefore metadata elements from a specific metadata format are formalised in terms of this intermediate representation. Then, mapping relations between format-specific and generic concepts are described. Combining these two sets of mapping relations, mapping relations between a pair of metadata formats can be inferred. These inferred mapping relations are the basis to create mapping instructions in order to map a metadata document from one format to another. Since these mapping relations are based on a conceptual level only, additional information about data types together with context information is required. After linking this information with an appropriate set of mapping templates provided by a library, mapping instructions expressed as XSL (Kay M. (ed.), 2007) templates are created. Finally, executing these XSL templates enables a metadata mapping between a pair of metadata formats. The overall workflow of this approach is visualised in Figure 2. A detailed description of the approach can be found in (Höffernig M. (et al.) 2010).

Since our mapping approach features an intermediate representation of generic metadata elements serving as a hub for mapping between formats, hand-crafted one-to-one mappings between each pair of metadata formats are avoided and the mappings can be created automatically. Therefore mapping relations are easier to maintain as well as adding a new metadata format is done without side effects to existing definitions.

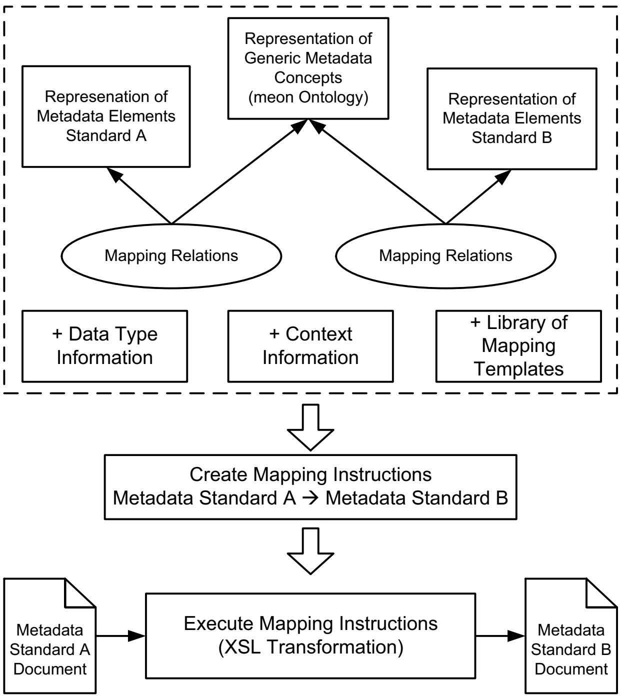

Figure 2: Metadata mapping approach

The core of this approach is the *meon* ontology (Höffernig M. (et al.) 2009) which describes generic metadata elements and the relations between them. *meon* was originally developed to model metadata elements used throughout the audiovisual media production workflow in a format independent way in order to support content exchange and its automation. The *meon* ontology has been extended to express mapping relations between metadata formats. In addition to the ontology of generic metadata concepts, specific ontologies are created for each format taken into account. Then it is possible to infer how concepts from different metadata formats are related by observing the relations among generic concepts and to the format-specific concepts.

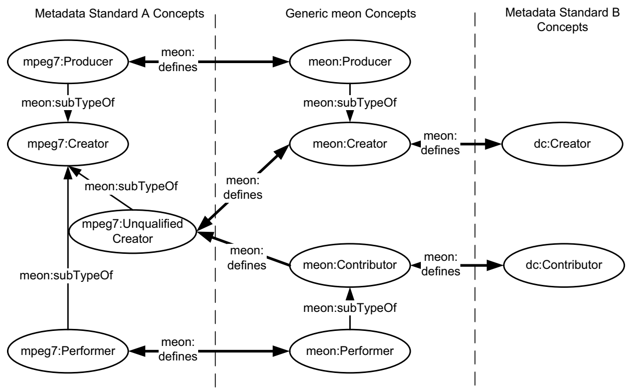

Figure 3: Example of the *meon* ontology for describing metadata elements and their relations

The *meon* ontology, expressed in OWL-DL (Coburn E. (ed.), 2010. LIDO - Lightweight Information Describing Objects. Version 1.0. http://www.lido-schema.org/schema/v1.0/lido-v1.0-specification.pdf (accessed 14 June 2012)

Dean M. (ed.), 2004), defines properties to describe definition and equivalence relations (property `meon:defines`) as well as subtype relations (property `meon:contains`). These properties can be applied on instances of class `meon:Concept` with its subtypes `meon:AtomicConcept` and `meon:CompoundConcept`.

In order to express mapping relations between metadata formats, the *meon* ontology has been extended. In addition to the ontology of generic metadata concepts, schema specific ones are created for each format following the *meon* pattern. Figure 3 shows a schematic example for the mapping of metadata elements from a metadata format A to another metadata format B via generic *meon* concepts, in this case `meon:Creator`, `meon:Producer`, `meon:Contributor`, and `meon:Performer`. It also models their relations, i.e. `meon:Producer` is a subtype of `meon:Creator`, `meon:Performer` is a subtype of `meon:Contributor`. In the same manner the format-specific concepts are defined and mapping relations via `meon:defines` properties are established (e.g. expressing equivalence between `mpeg7:Producer` and `meon:Producer`).

In order to retrieve mapping instructions between formats it is necessary to model the definition relations in more detail. Therefore additional data type information as well as context information is attached to the *meon* ontology. Then it is possible to select appropriate mapping templates to generate mapping instructions expressed as XSL templates which are applied to a given input document.

4. CONFIGURATION USER INTERFACE

As described in our mapping approach, any information which is necessary to determine mapping relations between a pair of metadata formats has been formalised with using the *meon* ontology. Additional information such as data type and context information as well as referencing mapping templates has been formalised by extending the *meon* ontology. Furthermore a logical reasoner is employed to infer new knowledge needed during the mapping process.

In order to hide the complexity of describing all this data in OWL style, we have developed a web-based GUI for managing all the required data for creation of mapping instructions. A screenshot of this configuration tool is depicted in Figure 4. This user interface enables editing and inspecting mapping relations between metadata formats and *meon* concepts as well data type and context information management needed to create mapping instructions.

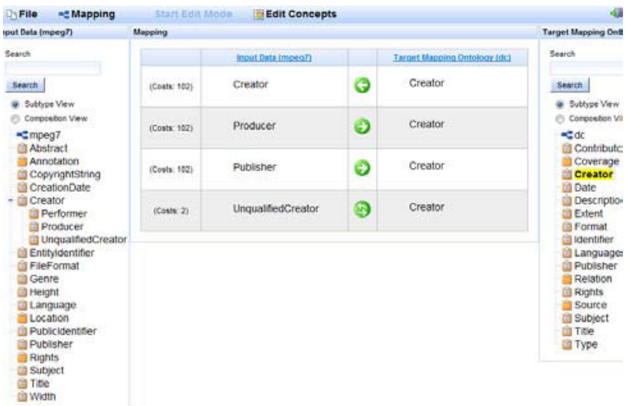

Figure 4: Screenshot of configuration user interface

In a typical use case the user selects an existing formalisation of a metadata format to work with or start to create a new one from scratch. On one side of the screen, concepts of the format-specific metadata representation are displayed using a tree structure, respectively concepts coming from the *meon* ontology are displayed on the other side (cf. Figure 4). In the middle of the screen current mapping relations are displayed. In this view new concepts can be added and existing ones can be modified. Furthermore mapping relations can be created by drag and drop or modified. In case a second format-specific representation has been selected, mapping relations between format-specific ones are inferred via the *meon* concepts and finally can be inspected as well.

Another view in the configuration tool provides the possibility to edit data type and context related information such as XPath references (Berglund A. (ed.), 2010) and attach these data to format-specific concepts. Editing the library of mapping templates is also addressed by the configuration tool. After all required mapping relations as well as additional data type and context information have been provided by the user, the configuration tool creates the resulting XSL document, which can be integrated in our applications.

5. APPLICATIONS & SERVICES

The mapping tools are available in an online and an offline manner depending on the current application where it is going to be used. This also depends on other matters as organisational structure, number of departments/persons involved and on the technical possibilities of the application site.

5.1 Web services for audiovisual archive systems

Archive systems of audiovisual archives allow ingest of media and their metadata, i.e. importing Submission Information Packages, (SIP) in OAIS terminology (ISO 14721:2003). After that often media are updated (e.g. for preservation purposes) resulting in updates of the corresponding metadata (i.e. change of Archival Information Packages, AIP). For consumption media files are extracted and packed with the necessary metadata into a Dissemination Information Package (DIP).

The first and last steps are in many cases automated processes. Media files are transferred from one place to another. Their locations along with the metadata are stored into the archive database. Before this can take place the transformation of metadata (i.e. the mapping) is needed. Thus a web service is provided which can be called by the overall ingest process before import into the metadata.

The use of this service may take some time depending on the size of the metadata description (which may become rather large e.g. in the case of MPEG-7 based descriptions). Further the service may be consumed by large parallel batch jobs. Therefore the service was implemented as a non-blocking interface. Calls are basically performed for triggering a mapping job and subsequent polls detect the status of pending jobs. The mapping service is implemented as a RESTful HTTP service (Fielding R., 2000) which can be used in a rather flexible and suitable way with most programming languages and system.

After a first step to find out which format identifiers exist the general sequence of calls for using the metadata mapping web service as shown in Figure 5 has to be performed: (2) define the new project-specific environment containing the necessary conversion settings; (3) upload the XML document available in the input format for mapping; (4.1) start the conversion process; (4.1.1) repeatedly check the status of the conversion process; keeping track of triggered conversions and result handling are part of the application which uses the service; the outcomes of these checks are foreseen as not finished/failed/success; (4.1.1.1) fetch the resulting XML which is available in the output format.

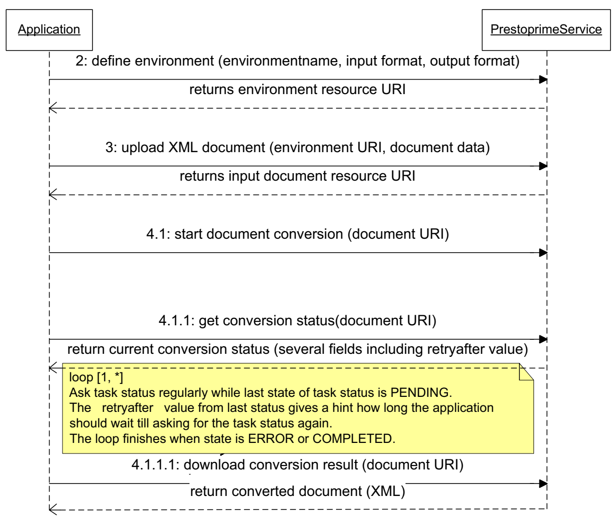

Figure 5: Sequence diagram of one conversion

Beside the aforementioned service calls the web service interface further includes functionalities to delete documents from the server and also to stop previously initiated jobs.

For purpose of visualisation and providing others with a test system a web front end (Figure 6) to the mapping service was developed. It includes some exemplary mappings and is available at prestoprime.joanneum.at.

5.2 Applications for museums and general archives

The products *imdas pro* and *archivis pro* are available as native Windows applications but also as web based applications. For the following we refer only to the native application but similar approaches apply to the web applications. Both applications allow the administration of museum objects and archival material. The metadata for such objects and references to accompanying media files are stored in a relational database.

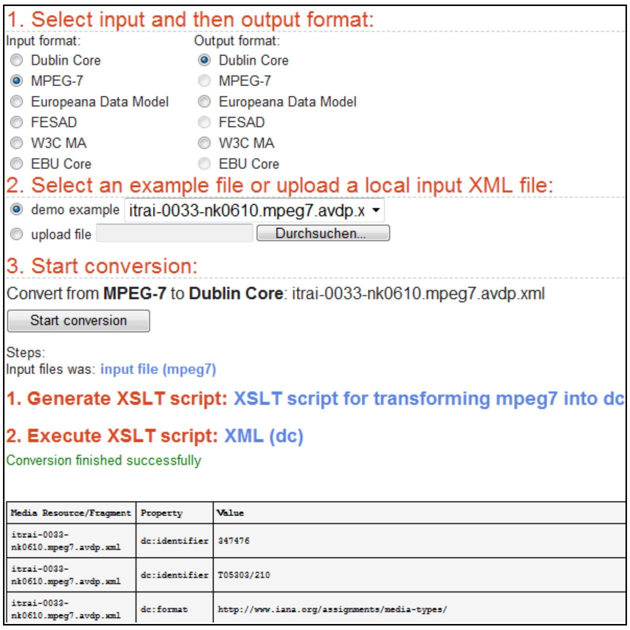

Figure 6: Web front end to the mapping service

The database schemata of the applications allow a very flexible approach with regard to metadata fields (their representation, cardinality and also to their labelling).

One of the wishes from customers is to export metadata to other systems, web portals like Europeana, Archives Portal Europe or other portals which accept metadata according to e.g. the LIDO (Coburn E. (ed.), 2010) or EAD (Encoded Archival Description, 2002) descriptions. Due to the flexibility of the data model nearly each installation has undergone some customisation. These customised software versions thus require a specific mapping to the potential export formats.

As described in the previous sections a mapping is mainly described through a number of XSL style sheets which are used to process an input document in a given format with (several) XSLT to create a document according to the desired output formats (e.g. LIDO, EAD, Europeana EDM (Europeana Data Model, 2012)). The XSL style sheets can be created manually which is a cumbersome and time consuming task. Furthermore it can be a hard or even impossible challenge to get the style sheets correct. Therefore the configuration tools allow creating

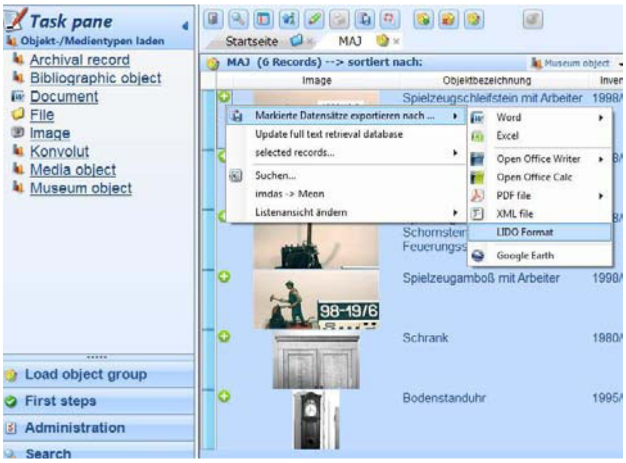

Figure 7: Exporting selected records according to the LIDO format within *imdas pro*

the necessary style sheets as an output of a user oriented graphically assisted definition process.

The *imdas pro* and *archivis pro* applications have implemented an XSL transformation engine which can use such style sheets. The style sheets themselves become available in the applications by importing into the product's database. Achieving the style sheets can be done according to one of three ways: (a) standard mapping directly available in the product database and download of some other pre-defined mappings from a server at JOANNEUM RESEARCH; (b) using the configuration tool on a server at JOANNEUM RESEARCH to create new mappings; (c) installation of the configuration tool within an institution's network and use of this tool to define mappings. Defining configurations as in (b) and (c) can be based on already existing ones or can start from scratch.


```
<?xml version="1.0" encoding="UTF-8"?>
<lido:lidoWrap xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:lido="http://www.lido-schema.org" xsi:schemaLocation="http://www.lido-sc
lido-v1.0.xsd">
 - <lido:lido>
     <lido:lidoRecID
       lido:type="local">D8AFA613456AF96FCE4BAF9E2497B177</lido:lidoRecI
   - <lido:descriptiveMetadata>
     - <lido:objectClassificationWrap>
       - <lido:objectWorkTypeWrap>
         - <lido:objectWorkType>
             <lido:term
               lido:encodinganalog="Objektbezeichnung">Spielzeugdamp
               mit Zubehör</lido:term>
           </lido:objectWorkType>
         </lido:objectWorkTypeWrap>
       + <lido:classificationWrap>
       </lido:objectClassificationWrap>
     + <lido:objectIdentificationWrap>
       <lido:eventWrap/>
     </lido:descriptiveMetadata>
   - <lido:administrativeMetadata>
     + <lido:recordWrap>
     - <lido:resourceWrap>
       - <lido:resourceSet>
         - <lido:resourceRepresentation>
             <lido:linkResource>D:\Database\Imdas\1998_19_1_9.tif</lid
           </lido:resourceRepresentation>
         </lido:resourceSet>
       </lido:resourceWrap>
     </lido:administrativeMetadata>
  </lido:lido>
```


Figure 8: Record exported in LIDO format

After storing the style sheets in the database the new mapping can be chosen in the application (as shown in Figure 7). The specific transformations will be applied on the selected data sets in order to produce the desired output format. In a single license environment records are created and available on that one particular computer. In a client/server installation of *imdas pro* style sheets are created, imported into the central database and available to clients from that moment.

An example output is shown in Figure 8. It was created through the selected records from Figure 7 and a basic mapping definition of the available source elements (e.g. “Objektbezeichnung”; attached media like “Image” are stored as references to the places where the files are stored) to the mandatory elements in LIDO.

6. CONCLUSION

In this paper we have presented an approach for automating mapping between different metadata formats, in order to overcome interoperability issues between cultural heritage institutions and facilitate content provision to portals like Europeana and Archives Portal Europe. The mapping approach uses an intermediate ontology and formalises the relations to each of the metadata formats supported. An intuitive web-based configuration user interface is provided in order to build and customise mappings. We have presented two applications of the proposed mapping approach: as a web service, which can be included in processes of an audiovisual archive’s preservation system, and the integration of the generated mapping instructions into collection management applications for museums and archives. The proposed approach reduces the effort for defining metadata conversions and thus facilitates access to the memory institutions’ collections.

7. ACKNOWLEDGEMENTS

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DIVERSITY AND TAXONOMY IN CULTURAL HERITAGE

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KEY WORDS: Cultural Heritage Diagram (CHD), Universal Cultural Heritage Classification, Cultural Taxonomy, Cultural Heritage Preservation, Culture Categories, backbone of the Culture

ABSTRACT:

The discipline of Cultural Heritage is nowadays developing very well. Moreover, the field of Cultural Heritage Preservation is also developing well. The necessity of well-organized taxonomy and classification now seems to be an outstanding significant topic. The scope of this paper regards such taxonomy; more precisely, it proposes this kind of taxonomy. The final products of this paper are the *Diagram of Cultural Heritage & its Preservation* and the *Universal Cultural Heritage & Preservation Classification* ($_{U}CH\&P_{C}$). The Cultural Taxonomy proposed here is expected to offer additive features of significant value (as for instance order, efficacy, clarification, simplicity, supervision etc.) distributed all over the individual fields of Cultural Heritage. The products of this paper are the innovative outcomes of a multifaceted research endeavor.

1. INTRODUCTION

We present in this article a scheme of classification for Cultural Heritage. The latter field (Cultural Heritage) is now an area with ongoing interest and research. Its inherent nature as well as the aforementioned special interest, tends to turn Cultural Heritage into a gigantic individual corpus. After that, the necessity of supervision and control in this field becomes obvious. We focus here on the hierarchical organization of the independent or cross-correlated fields of Cultural Heritage and its Preservation. Finally, we offer means for classifying the abovementioned hierarchized Cultural Heritage. A manifold and long research endeavor results in the outcomes presented here.

2. CULTURAL HERITAGE PRESERVATION DIAGRAM [C(H&P)D]

It is evident that in order to sufficiently understand a field (subject, meaning etc.) an observer must initially comprehend the etymology of the name describing the field under examination. We thus give at this point a definition of the term ‘Cultural Heritage’. We cite herein simply the definition with no further analysis.

Cultural Heritage is the complete space of products/objects of Culture originated from the distant Past until now.

Initially, we should observe, regarding our subject, three implicated areas. These areas are hierarchically:

(a) *Culture*
(b) *Cultural Heritage*
(c) *Cultural Heritage Preservation*

However, for the sake of simplicity we may abbreviate by writing as follows:

Cultural (Heritage (Preservation))

where this notation is suitable.

Hereinafter, we demonstrate a panoramic view *of the whole of Culture,* resulting from a thorough study. In order to successfully demonstrate this view, the most succesfull approach is by using a hierarchical diagram (*the backbone of the Culture*). This diagram (*the **C**ultural (**H**eritage (**P**reservation)) **D**iagram* **[C(H&P)D]**) is depicted in Fig.1.

In this diagram we should notice the (sequential) succession regarding the chain *Production – Heritage – Preservation*; moreover, the inner classification of individual areas of Cultural Heritage Preservation. It is evident that the herein presented diagram (Fig.1) is an open diagram which can be continuously extended.

3. CATEGORIES OF CULTURAL HERITAGE PRESERVATION

In the aforementioned diagram we should initially consider the following fundamental categories of culture preservation, i.e.

(1) technical
&
(2) digital

The term ‘technical’ incorporates all those means which contribute to the physical or materialistic preservation of cultural elements (e.g. restoration (Conti & Glanville, 2007), reconstruction etc.). The term ‘digital’, on the other hand, refers to each tool which helps preserve cultural elements by means of computers and digital technology (MacDonald, 2006). However, there are means which fall into one or the other category or, even, in the cross-section of them. Such a characteristic example is the use of lasers in Cultural Preservation (Fotakis et al., 2006).

Moreover, there are also other supplementary categories of preservation such as for instance *audio-visual* and *chemical,* which could be characterized as (a) subareas of the previously mentioned general categories of preservation, or (b) bilateral fields.

At last we should refer, as independent fields of Cultural Heritage Preservation, the *traditional* categories of Cultural Information Preservation, i.e. the *imprinted* and *oral* ones. Therefore, we may form the fundamental triptych of Cultural Heritage Preservation -with reference to its kind- as

(digital, technical, traditional)

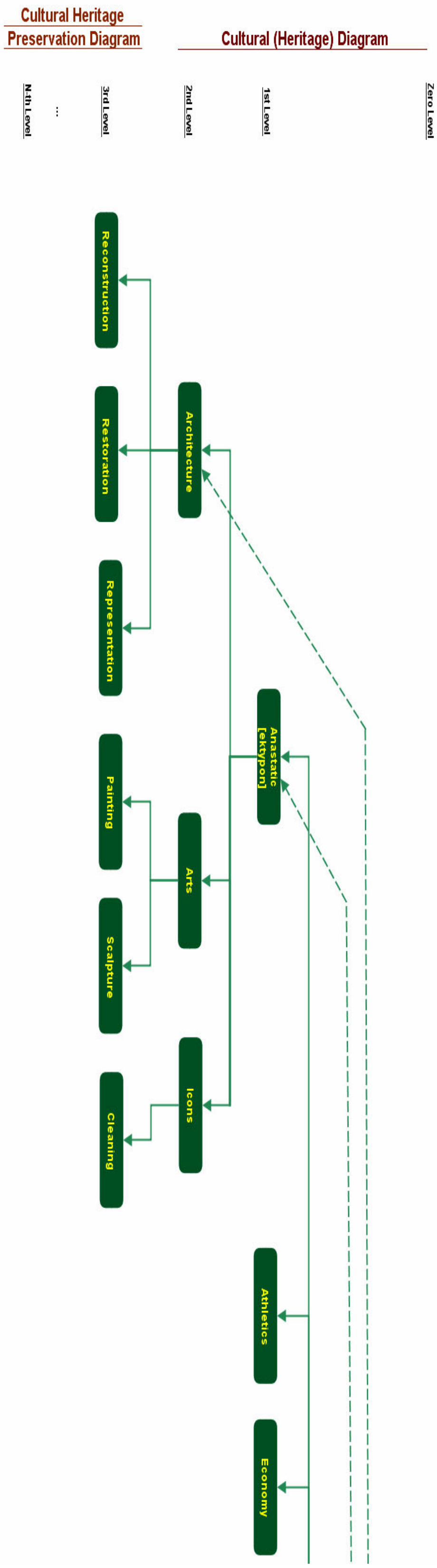

Figure 1: Part 1/4

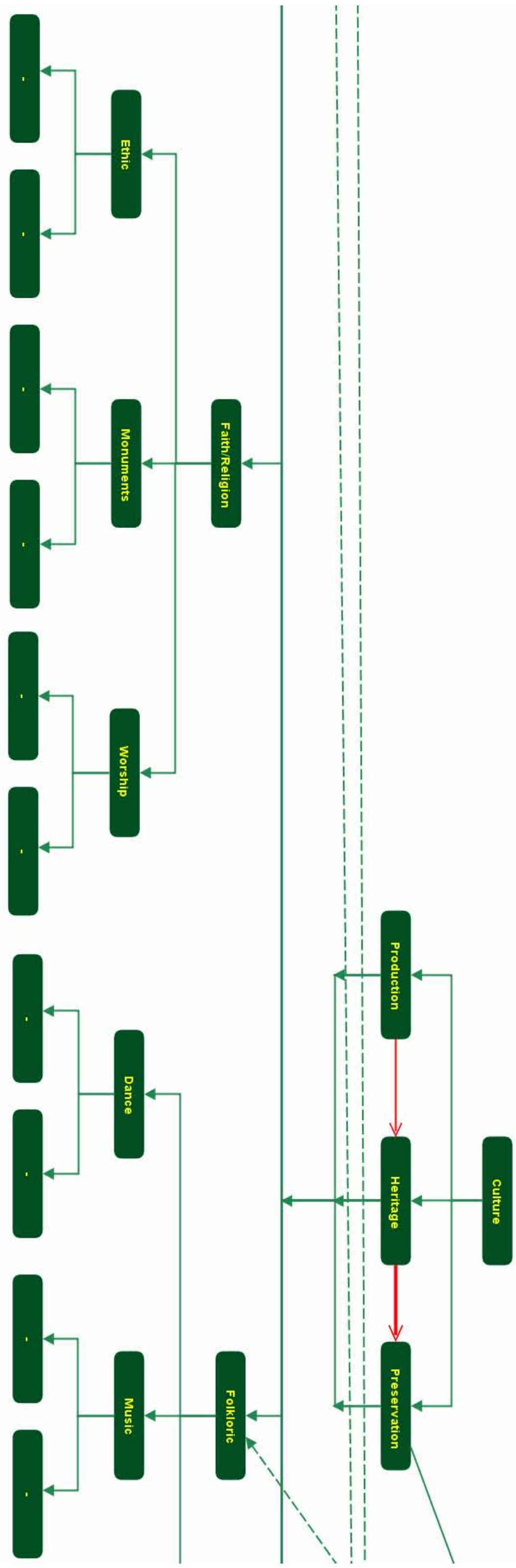

Figure 1: Part 2/4

Figure 1: *The **C**ultural (**H**eritage (**P**reservation)) **D**iagram* **[C(H&P)D]**

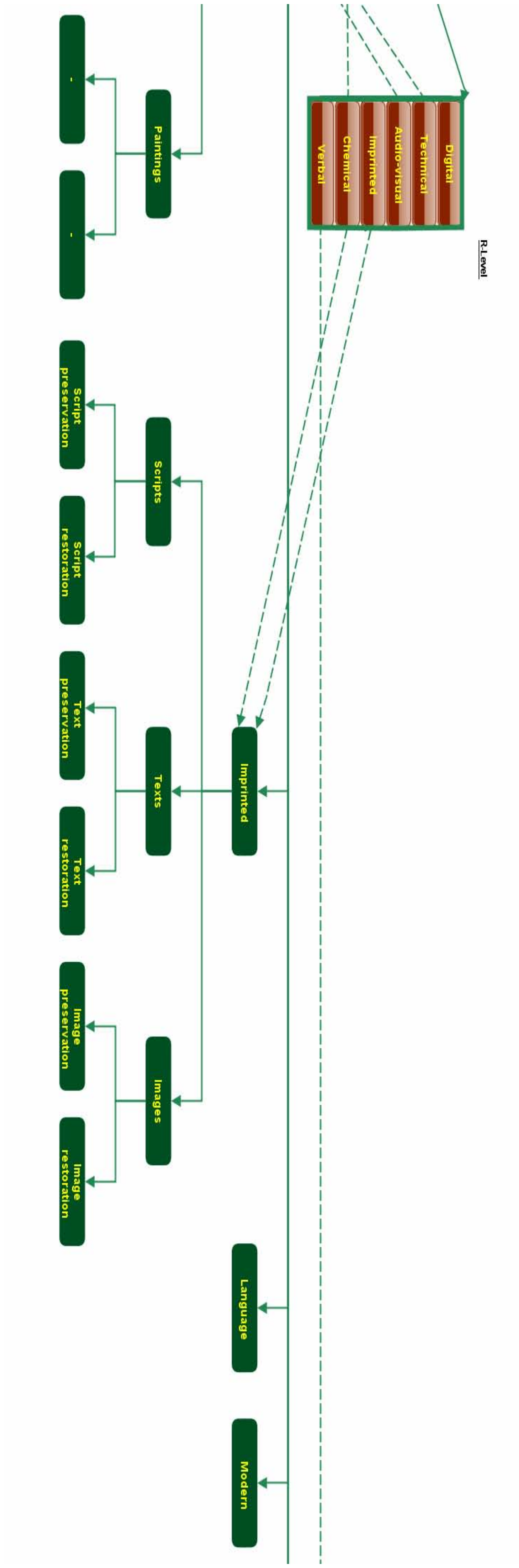

Figure 1: Part 3/4

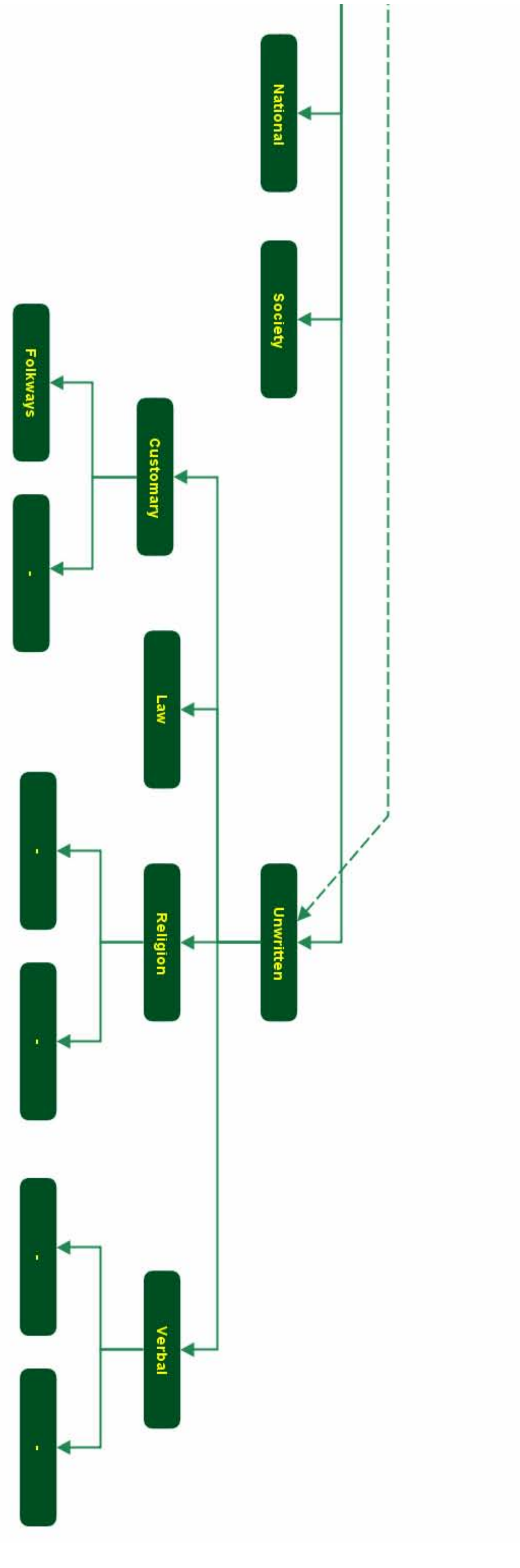

Figure 1: Part 4/4

Figure 1: *The **C**ultural (**H**eritage (**P**reservation)) **D**iagram* **[C(H&P)D]**

The assembly of all the previously mentioned classes of Preservation is encompassed in Table 1.

4. THE UNIVERSAL CLASSIFICATION SCHEME ($_U$CH&P$_C$)

We now demonstrate the major product of the previous diagram [C(H&P)D], i.e. the ability to globally classify the whole area of Culture or, in other words, of the Cultural Heritage Preservation. Attempts to systematically process Culture could also be found in the literature (e.g. Hofstede et al., 2010).

According to Fig.1 we can construct a universal subject classification scheme regarding Culture and Cultural Heritage Preservation, namely the **$_U$CH&P$_C$ (U**niversal **C**ultural **H**eritage **& P**reservation **C**lassification**)**. This universal classification of Culture will strongly enhance the general effort to systemise, clarify, process and promote Culture (see for instance (American Mathematical Society, 2010)). Moreover, it will contribute in conjunction with other universal efforts to efficiently resolve the megatheme of Culture (UNESCO (Frey & Pamini, 2009) etc.)

The structure of this classification model is illustrated in Table 1; the zero level refers to the *phase of the Culture* and is codified according to the code P-H-R (*stands for Production-Heritage-Preservation*). The rest of the coding scheme is also depicted in this Table. The distinctive feature of cultural preservation is – of course – its kind. The *R-level* (Table 1) refers to the Preservation and illustrates the different types of it. Thus, it is very important to classify cultural objects into ontological families (*1st level*), i.e. larger assemblies embodying distinct entities, using as criteria their fundamental and characteristic inherent forms (e.g. the materialistic structure of the entity, how the entity is constructed, its cross-references etc.). The *2nd level* incorporates the characteristic kinds of cultural objects. Finally, the distinctive procedures which refer to the global process of Cultural Preservation are accumulated in the 3rd level. We should of course notice that the classification progress can proceed further in order to encompass more explicit works and processes in Cultural Heritage Preservation.

We proceed now by citing an instance of this classification scheme regarding the case of *scripts' restoration*; that is, the classification code *R-ff-14-F* (according to Table 1). Furthermore, if it is necessary to specify the type of preservation (e.g. chemical) then we shall rewrite the code as *R-c- ff-14-F.*

We finally give a sample (instance) of the Universal Cultural Heritage Classification ($_U$CH&P$_C$) according to Fig.1. This instance is illustrated in Table 2. The C(H&P) Diagram can be even more analytic, by incorporating more aspects and facets. Thus the $_U$CH&P$_C$ scheme could be more explicit too. Therefore we acquire through this process the ability to supervise and analytically know, in depth, the overall space of Cultural Heritage Preservation.

5. CONCLUSION

A specific paradox of contemporary era is obvious: the nowadays human civilization recapitulates the overall civilization of the preceding History. People during previous centuries, were creating culture all over the world; the advantage of the present era is the ability -based on its technological civilization- of storing, processing and evaluation of the overall Culture which has already been created in the past. The necessity, consequently, of a unified and systematic classification and taxonomy of the huge field of Culture becomes evident and imperative. The herein proposed *Universal Cultural Heritage & Preservation Classification* ($_U$CH&P$_C$) scheme fulfills this need. The expected value of this classification scheme is yet inestimable.

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Zero level Phase			
P	**H**	**R**	
		R- level Type	
		oa	**audio-visual**
		c	**chemical**
		e	**digital**
		i	**imprinted**
		t	**technical**
		v	**verbal**

Code	**1st level Ontology**
aa	**Anastatic [*ektypon*]**
bb	**Athletic**
cc	**Economy**
dd	**Faith/Religion**
ee	**Folkloric**
ff	**Imprinted**
gg	**Language**
hh	**Modern**
ii	**National**
jj	**Societal**
kk	**Unwritten**
	…

Code	**2^{nd} level Object**
01	**Architecture**
02	***Dance***
03	***Ethic***
04	***Folkways/ Mores***
05	***Icons***
06	***Images***
07	***Law***
08	***Monuments***
09	***Music***
10	***Paintings***
11	***Pottery***
12	***Religion***
13	***Scalptures***
14	***Scripts***
15	***Texts***
16	***Tools***
17	***Verbal***
18	***Worship***
	…

Code	**3rd level Process**
A	**Cleaning**
B	**Preservation**
C	**Reconstruction**
D	**Recording**
E	**Representation**
F	**Restoration**
.	**…**

Table 1: The hierarchical structure of the classification model $_{U}CH\&P_{C}$ (Universal Cultural Heritage & Preservation Classification)

Code	***Category***		***Code***	***Category***
aa-xx	**Anastatic [*ektypon*]**		**ff-xx**	**Imprinted**
aa01	*Architecture*		…	...
aa01C	Reconstruction		ff06	*Images*
aa01E	Representation		ff06B	Image preservation
aa01F	Restoration		ff06F	Image restoration
…	...		ff14	*Scripts*
aa05	*Icons*		ff14B	Script preservation
aa05A	Cleaning		ff14F	Script restoration
…	...		ff15	*Texts*
aa10	*Paintins*		ff15B	Text preservation
…	...		ff15F	Text restoration
aa13	*Scalptures*		**…**	**…**
aa13A	Cleaning		**gg-xx**	**Language**
..	…		**hh-xx**	**Modern**
bb-xx	**Athletic**		**…**	**…**
cc-xx	**Economy**		**ii-xx**	**National**
dd-xx	**Faith/Religion**		**…**	**…**
dd03	*Ethic*		**jj-xx**	**Societal**
dd08	*Monuments*		**…**	**…**
dd18	*Worship*		**kk-xx**	**Unwritten**
..	**…**		*kk04*	*Folkways/ Mores*
ee-xx	**Folkloric**		kk04D	Recording
ee02	*Dance*		*kk07*	*Law*
ee09	*Music*		*kk12*	*Religion*
ee10	*Paintings*		*kk17*	*Verbal*
...	...		**..**	**…**

Table 2: An instance of the Universal Cultural Heritage & Preservation Classification ($_U$CH&P$_C$)

HOW TO BUILD A DAM AND SAVE CULTURAL HERITAGE

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KEY WORDS: Archaeology, Cultural Heritage, Dam, Dams, Development, Hydropower, Guidelines, Policy, Water

ABSTRACT:

The impact of each dam on cultural heritage is enormous, affecting hundreds or even thousands of sites. Dams are required, however, to offset water shortages and provide electricity for a rising global population. This short paper describes the initial outcomes of a new project, the aim of which is the production of a practical set of guidelines for cultural heritage management before and after dam construction, aimed at developers, foreign contractors, and policy-makers.

1. INTRODUCTION

1.1 A Call for Action

The conference, How to Build a Dam and Save Cultural Heritage, was conceived in response to a one-day conference held at Durham University in the spring of 2011. The conference "Iraq: Archaeology, Cultural Heritage and Conflict" brought together experts from law, archaeology, and cultural heritage, including a key advisor to the military on cultural heritage protection. Over the course of the day, however, it became clear that the primary source of damage to cultural heritage there is not the conflict but development. The discussion session that followed highlighted an urgent situation.

In the audience that day was a developer who had just been awarded a contract in the Middle East with an impact area of about 5,000 sites. Concerned about the impact his development project would have on the sites, he travelled to the conference with a specific question in mind: How do I choose which sites to save? In a room of experts, no one could give him specific, practical advice. Shockingly, in 2011 there were no guidelines to refer to or best practices to follow, only calls to write them.

How can we criticize developers whose projects destroy sites, if we are not prepared to help those who care?

1.2 The Foundation of How to Build a Dam and Save Cultural Heritage

> *"Cultural Heritage is an expression of the ways of living developed by a community and passed on from generation to generation, including customs, practices, places, objects, artistic expressions and values…As part of human activity Cultural Heritage produces tangible representations of the value systems, beliefs, traditions and lifestyles."* (Culture in Development, n.d.)

Moreover,

> *"A sense of place, purpose, and belonging tend to be good for us psychologically…. far from being "just another" factor that impinges upon the health of individuals, social identities—and the notions of "us-ness" that they both embody and help create—are central to health and well-being"* (Haslam et al., 2009: 2-3).

Yet the population is increasing – the UN estimates the population will reach 10 billion people by the turn of the next century – and these people have a right to water, food and power, too. The majority of large dams are built for irrigation – current estimates suggest 30 – 40% of irrigated land now relies on dams (Niasse and Wallace, 2002). The majority of major dams are built for hydropower; dams generate nearly a fifth of the world's electricity. There are over 800 000 dams globally, of which more than 40 000 are large dams, and 300 are major dams (>150m tall, with a particularly large reservoir). So far, over 400 000km^2 of land has been flooded according to International Rivers (2007). Is there a way forward, and if so, what is it?

This project must also nod towards another source of inspiration – a workshop held in Corinth more than a decade ago, which considered the nature of threats to sites in the Mediterranean, and began to consider a framework in which to move forward. The workshop took as its starting point that conservation efforts are usually focused on material decay, but in the last decade it has become increasingly clear "that threats to the survival of this heritage come from a vast array of sources, but most of them are linked to the way modern societies are developing" (Palumbo 2002: 3). Acknowledged then and still true now, there is little consensus on the nature of that heritage – it is not a 'universal' concept, nor is preservation, or even of audience for which something may be preserved, and these areas are still hotly contested (for examples, see Meskill, 2009). What is preserved, why, and who for, are all questions that this project must deal with, to which no easy answers are available.

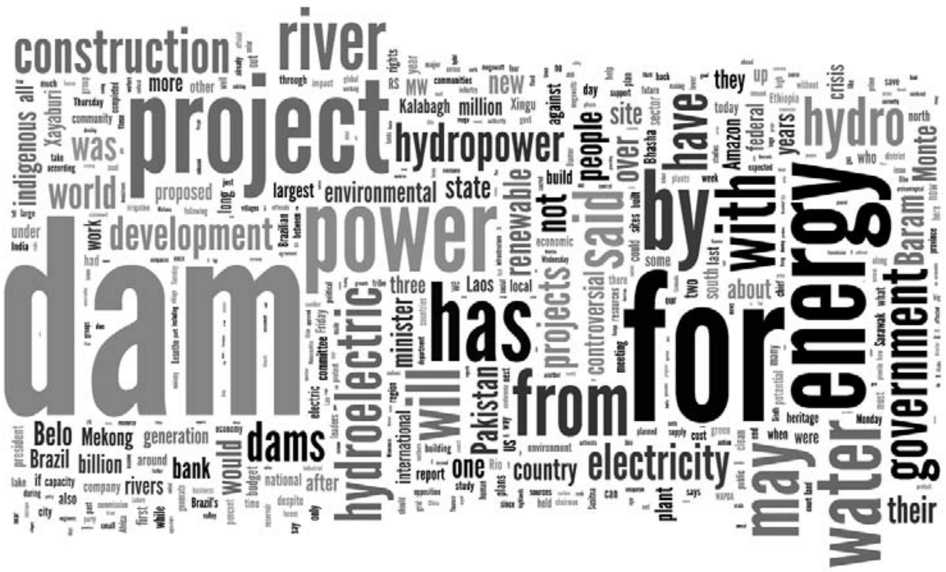

Figure 1: Word cloud displaying the relative frequency (through font size) of words in news article titles and summaries relating to dams and cultural heritage between April 1st and July 31st.

Less than a year later, the project How to Build a Dam and Save Cultural Heritage launched with funding from a grant offered by the Durham University Department of Archaeology. Further sponsors of the project include AAG Archaeology, Arch Points, Institute of Hazard and Risk Research, the Centre for the Ancient Mediterranean and Near East, and CARD (all of Durham University), Tally Fox and The Water Network, to whom we are extremely grateful. The project is run jointly with Edinburgh University School of History, Classics and Archaeology, sharing practical expertise on the effects of dam projects.

We have chosen to focus initially on dam development due to the current global issues of increasing demand for water and electricity on a planet whose population continues to increase. We note, however, that it is estimated that 40 – 80 million people have been displaced by dam projects, and many more are at risk from current projects (International Rivers, 2007). A decision was made at the outset of this project that we cannot and should not ignore the social impact of dams, and nor would we want to, as heritage is created by and used by people. However, our intent is to focus on the impact on cultural heritage.

The danger in choosing to take a global approach is the risk of loosing the individual site, of overlooking something unique in the attempt to provide unified guidelines. Furthermore, every dam is unique, designed specifically for its purpose and context. Yet, however unique these sites are, they share common threats, designed by organisations with similar goals supporting people with similar needs, and it is these similarities we hope will offer a way forward.

1.2 Aims and Objectives

Although based in the UK, the ultimate aim of How to Build a Dam and Save Cultural Heritage is the publication of a practical set of international guidelines for cultural heritage management before and after dam construction aimed at developers, foreign contractors, and policy-makers. In order to achieve this in a way that has real impact in the world, it is crucial that experts from all relevant fields, and from different perspectives, are represented from the beginning. Inclusiveness both between different fields within academia, but also between academia and industry/practitioners, is a key objective that is seen as vital to the project's success, combining in depth study with real, practical experience.

In these early stages, however, a key aim is to identify these issues in order to construct a platform from which to proceed, identifying the main areas in which guidelines are required. This is an ongoing activity, managed through the project website: https://sites.google.com/site/saveculturalheritage/

2. WHAT PEOPLE WRITE ABOUT

Vital to this is the capture of information. To truly deal with the issues on a global scale in any way that remains meaningful at the level of an individual dam project, information must be current, it must be relevant, and it must be shared. Every day, this project website is updated with the latest news from around the world regarding new and ongoing dam and hydropower projects, new hydropower technologies, the impacts of dam and hydropower projects on culture and cultural heritage, and new legislation on dams and hydropower.

Over the three month period between April 1st and July 31st of this year, this has resulted in 579 unique articles about dam projects around the world and the impact dams are having on cultural heritage. To try to convey the trends in what people write about when they write about dams, figure 1 is a word cloud using words that appear five or more times in the titles and article summaries in at least one month of this four month time period.

While the words (frequency in brackets) "archaeological" (13), "cultural" (12), and "heritage" (27) do appear, other issues like "energy" (263), "water" (183), and even the "environment" (27) or being "environmental" (56) take precedence in the dialogue about dams. Encouragingly, "indigenous" (62) appears strongly with 47/62 mentions occurring during or after the Rio+20 conference held in late June.

3. THREATS TO SITES?

3.1 Current research in the field

The threats sites face during dam construction are poorly documented, and even more poorly understood by both archaeologists and developers. In a working paper submitted to the World Dams Commission, Brandt and Hassan (2000) discuss numerous issues affecting cultural heritage management and dam development, not least of which was a lack of adequate training amongst personnel, and poorly enforced / implemented legislation.

Even when these are not an issue, the risks to sites are still assumptive. Notable pre-construction impacts (assuming an environmental assessment of heritage takes place) include the lack of information regarding site location, and site registration – if sites are not registered then there is no-one to say dams are affecting them. Given the ongoing taphonomic process at work in the landscape, archaeologists should not expect a complete record of sites to ever exist, but many areas are un-surveyed and the work is hampered by a lack of consensus about what even constitutes a site (Wilkinson, 2003). This has led to an over-focus on larger sites at the expense of landscape features, such as roads, field systems, water management, and other elements of landscape use. The proliferation of articles discussing the discovery of many hundreds of new sites using satellite imagery in the last decade attest to the fact that many new discoveries remain: the true damage caused by dams is almost certainly under-estimated. Other threats include the obvious and ever present bulldozer utilized in the creation of the infrastructure, but even here, the nature of damage is an assumption. Destruction is assumed to be total, but evidence suggests that changes in ground level can preserve several meters of site below the ground (Wilkinson and Tucker, 1995). Research is also only just beginning on the disturbance caused to these buried deposits (Cunliffe, unpublished), and on the effects of sites that are only partially damaged.

Once the dam is built, and the reservoir area is inundated, there is also a lack of information about what happens next. The actual damage is the subject of many incorrect assumptions: there is surprisingly little fact, but a great deal of work is carried out as if the facts were known. Most studies are limited in nature. Some (e.g. White, 2000) have examined impacts to shoreline sites, and others (eg Norr and Faught, 2000) have examined certain site types exposed when reservoir levels have dropped. Lenihan (1981) conducted the most comprehensive study, detailed in section 3.2. The team dived on inundated sites in northern America reservoirs, and assessed the various impacts (physical, chemical, and biological) on sites and the wider archaeological landscape within different areas of the dam. One particular finding contested the "certainty" that burying an exposed site under sand before inundation will preserve it, seen recently, for example at the Roman baths at Allianoi, Turkey (Global Heritage Fund 2010), showing that it is not always an appropriate course of action. Lenihan also evaluated the appropriateness of the traditional response of the archaeological community to the threat of inundation: in particular he criticized the large site-specific rescue excavations often conducted on 'important' sites, chosen on spurious criteria. It is sad to see that more than thirty years later, this approach is still common, and this study has not been repeated elsewhere on such a scale.

It is also appears widely believed that once the dam is built, nothing more will happen to the heritage of the area, and nothing more can be done - another fallacy. Erosion on sites continues, particularly to those on the shoreline, but also to those in areas of higher water flow rates (Lenihan, 1981, Stammitti, unpublished). Post-inundation managerial action can act to mitigate some damage, but is rarely implemented. Impacts downstream of the dam, where the river will doubtless change, are not always considered, and nor are the peripheral infrastructure results from the building of the dam. Dams lead to increases in urban development, in the supporting infrastructure (roads, cables, etc), in arable land, in intensification of exploitation of existing land, and in the building of large irrigation projects that could potentially be more destructive to sites than the dam (Wilkinson and Tucker, 1995; Wilkinson and Cunliffe, 2012).

3.2 Previous Projects: The National Reservoir Inundation Study

Prior to Stammitti's research, the only other project of a similar nature was the aforementioned study by Lenihan and his team in North America. Like this Project, their survey arose from an effort to "find practical and demonstrable solutions, at the field level, to commonly shared problems faced by field managers in the conservation management of inundated cultural resources" and sought to answer the question "how should we manage the long-term preservation of inundated archaeological resources?" (Scovill in Lenihan 1981: v). The study acknowledged the crux of the debate: to excavate sites prior to inundation and thus 'save' them, or to bury them for the future? There was little to no data to support either viewpoint.

The study took place over five years and involved a comprehensive literature review, and ground-breaking new research by both the core team and a series of contracted reports on certain specialist topics, diving on dams and scientifically analyzing the results.

(Very) briefly summarized, they came to the following conclusions.

- The overall effects of reservoir inundation on archaeological resources are detrimental, resulting in large scale destruction of the resource, therefore the inundation process should not be viewed as a means of creating a data bank.
- The traditional response of the archaeological community to the threat of inundation is "ill-conceived and parochial" (1981: 5), ignoring the inter-site record, such as environmental remains, in favour of large sites, and assuming inundation affects all remains equally, which it does not.
- Site protection is only a viable alternative to excavation in very specific circumstances. Preservation is not an answer in and of itself, as some elements of a site will always be lost over time. Therefore it should be considered together with (at least) partial excavation. Indefinite commitments to site protection are not always possible.
- The effects of different reservoir zones on sites is poorly understood, and rarely taken account of.
- Post-inundation managerial action should play a much larger part in mitigation. Responsibility does not stop with inundation.

- There is a need for great communication between reservoir planning and construction personnel, and archaeologists. “There are points in the reservoir construction process where increased dialogue and commitments may result in increased protection of resources at reduced expense” (1981: 6-7).

The report concludes that whilst a vast amount of hard data was generated to support some conclusions, in other cases concluding statements were only weakly justified and open to considerable controversy. Furthermore, they noted that due to the unique nature of most reservoirs, there would probably be new variables they had not considered.

The conclusions of the report are still valid today, but the report was never widely circulated – most archaeologists, and even fewer engineers, have not even heard of it, although many of its recommendations (particularly the last one) ring as true today as they did thirty years ago. However, the study was undertaken in only one country, dealing with only one legal framework, and with one main intended audience agency – the National Park Service of the U.S. Department of the Interior. There is no mention of whose heritage the archaeologists are dealing with, or of working with local communities in the key recommendations. Many more reservoirs have been built, with new unique situations. Furthermore, technology has moved on since this study was carried out, and much more data could potentially be gathered. Lenihan’s study forms an excellent basis for this project, considering many of the key issues, but there is an undeniable need for more work to be done, and on a global scale. However, the crucial first step is to assess the state of the problem, thirty years on.

4. THE WORKSHOP

July 6-7, 2012, a workshop was held in Durham with live streams to Edinburgh and Istanbul to help set the foundation and framework of the project and to identify key issues surrounding cultural heritage before, during, and after dam construction. The workshop was well attended, with representatives from The British Dam Society, URS Infrastructure and Environment, the British Museum, NG Archaeology Services, and members of staff and postgraduates from the Universities of Durham, Edinburgh, Oxford, Newcastle, UCL, Ulster (N. Ireland), Kyoto (Japan), Pennsylvania (USA), Shah Abdul Latif (Pakistan). Talks covered every continent, giving a truly international perspective. Nonetheless, some common issues emerged.

Archaeologists, as caretakers of the past, protect and study its remains through recording. Excavation is a destructive process and the artifacts that result from either excavation or survey are stored for safe keeping, often at least partially in the archaeologists’ home country.

The prioritization of sites to record is based on scientific value and the requests of the funding body. Often, this can favor older sites such as, for example, Egyptian tombs and temples or Mesopotamian sites over ‘modern’ Islamic remains (with histories extending back more than a millennium). In this example, the priorities of the archaeologist and the local community are opposed. In predominantly Muslim countries of the Middle East, it is common to teach Arabic history starting only from the spread of Islam. In the processes of caring for the past, the desires and values of the local community and their relationships to the heritage are rarely considered. Beyond leaving communities feeling that their heritage is not valued, this practice can also have damaging effects on the local cultures.

Cultural heritage often plays a key role in a culture’s identity and ideology through active roles in traditions. The removal of cultural heritage either through physical relocation or rendering it inaccessible by some means (inundation, for example) can still result in a loss for the local community and destruction of cultural heritage – even if it has been properly recorded and/or conserved in a museum.

A current example of this gap between archaeological caretaking and protecting the cultural heritage of a local community is currently taking place in California. There, the Native American tribe Winnemem Wintu is engaged in an active fight with the state of California to stop the raising of the Shasta Dam in order to preserve the last puberty rock still above water. The rock plays an instrumental role in their women’s coming of age ceremony. One of the final activities of the ceremony is a swim across the river by the girl to this rock where instruction on womanhood and transformation to womanhood takes place. An ancient site, it has been properly recorded archaeologically. Scientifically speaking, it is ready for inundation from the proposed raising of the Shasta dam without loss of data. Practically, however, the flooding of the last rock will result in the destruction of cultural heritage and the mandatory end of a traditional transformation of girls to women.

The problem can be summarized as:

Cultural Heritage = Tangible Heritage + Intangible Heritage

Archaeologists are often only formally trained in recording and analysis of tangible heritage, objects and sites, but there is no neat line between past and present. The past is constructed, used, and reused continuously. A particularly famous example of past, present, solid and intangible intertwining are the Aboriginal dreamscapes of Australia. UNESCO has defined a term, cultural landscape, to describe the values of such locations as Aboriginal dreamscapes or the landscape of the Winnemem Wintu ceremony (1992, revised 2008).

> *“Cultural landscapes -- cultivated terraces on lofty mountains, gardens, sacred places ... -- testify to the creative genius, social development and the imaginative and spiritual vitality of humanity. They are part of our collective identity.”* (UNESCO, 2012)

Addressing this issue is a challenge. Already so-called rescue archaeology is operated on tight deadlines that cause the prioritization of sites, which would otherwise not take place. There is little time for consultation with local communities, much less the hiring of a cultural anthropologist to understand the intangible side of a community’s cultural heritage.

Archaeology is usually classified as a ‘soft’ issue. As a result, archaeologists are only involved after a dam has been planned, designed, a contractor hired, and construction is almost ready to begin. The consequences are that small changes in design, such as the raising of a dam to ensure a site is located in the anaerobic zone of a reservoir or the slight shifting of a spillway, become prohibitively expensive and sites are lost.

The need for data was also emphasized at the workshop. If we are to change the nature of our involvement, becoming involved sooner, and even becoming part of the design process, data is required. We need to know exactly the kind of damage that occurs to sites and materials in different situations and what conditions can be created to mitigate that damage. We need to know what to ask for, why it is necessary, and be able to provide data that engineers and developers can work with to create the desired outcomes. At present, such data does not yet exist.

Emily Stammitti, a director of this project, is expected to complete her Ph.D. studying exactly what happens to sites post-inundation by the end of the year. Stammitti's work represents the first attempt to expand Lenihan's study to other site types in other countries. Just as every dam is unique, so is every archaeological site, but it may be possible to create a typology based on the construction materials of sites that can be used as a basis for finding solutions.

Some of the requisite data could come from the development firms themselves. Many engineering companies acquire satellite imagery and aerial photographs of the impact areas of their projects, constructing 3D models of the terrain. This same data can be used by archaeologists for remote sensing purposes to map sites and features in their contexts, expanding the known archaeological resource, and enabling better planning of salvage work.

Finally, the dominant issue raised at the workshop is the need for dialogue and greater involvement between all participants, from governments and international bodies to affected local communities. All parties have a role to play in the construction of a practical set of guidelines and the protection of cultural heritage before, during, and after dam construction.

5. DISCUSSION

As archaeologists, we are extremely aware both of the importance of cultural heritage and the dangers it faces, especially from large development projects – dam projects included. Stammitti's practical underwater works (*in press*) in reservoirs throughout Scotland has produced new data about site conditions, typological categories, and the means to mitigate the effects of reservoir currents and sedimentation. The work, which investigated a cross-section of reservoirs and contained archaeological sites, was carried out with the cooperation of the Biggar Archaeology Group, using nonintrusive underwater survey techniques. Cunliffe's work (*in press*) using satellite imagery to monitor change to archaeological sites in Syria has demonstrated the extreme magnitude of the impact development has on archaeological sites. A study in the region of Tell Beydar, just north of the West Hasseke dam, demonstrated that cultivation expanded, urban development increased, and sites noticeably degraded. The intensification of agriculture as a result of the increased availability of irrigation water is a rarely considered impact. As the land is already given over to agriculture, it is discounted in impact assessment. However, increasing irrigation allows greater crop rotation and encourages greater exploitation of the land, with consequently detrimental effects on the sites within that land. Nonetheless, the world's growing population requires access to safe drinking water, irrigation to grow crops, and homes safe from floods, along with equal access to electricity and the benefits it brings. We do not seek to sacrifice the future for the sake of the past, but nor do we wish the past to be lost in the search for the future. Lenihan (1981), ICOMOS (Niasse and Wallace, 2002), and even the World Dams Commission (2000), amongst others, have all made recommendations for ways to preserve cultural heritage whilst still recognizing the need for hydropower projects, yet these recommendations remain largely unknown. We must seek dialogue to move this issue from the impasse in which it now languishes.

The creation and use of dams is about more than just power, food and people. Water has many symbolic meanings, and these meanings affect patterns of use and attitudes to water conservation (Strang, 2004). Perceptions of dams, and of water, are complex, and influence us more than we realize, with underlying issues of power and ownership at play. This dialogue must acknowledge these influences, and the popular misconceptions present on both sides. Dams are not just about 'crisis' and 'solutions', but about people - past, present and future.

6. WHAT IS NEXT?

As How to Build a Dam and Save Cultural Heritage moves forward, we are seeking funding to become a full-time project for the next three years. During this time, we intend to:

- Investigate key questions regarding the connection between cultural heritage and identity and the effects of separation from cultural heritage by destruction, inaccessibility, removal to distant museums, etc.
- Build a body of data on the effects of dams on cultural heritage over time through remote sensing and field investigations, including continued work by director Emily Stammitti diving on reservoir sites to record the effects of inundation at different depths.
- Work with engineers and developers to gather data and information about dam construction and the types of design changes that are practical.
- Work with engineers, policy-makers, and developers to raise awareness of the importance of cultural heritage and the value of changing when cultural heritage becomes involved in a project timeline.
- As we move forward, those involved need to recognize that in such an interdisciplinary effort, terminologies are bound to conflict or be misunderstood. It is key that everyone involved can be understood, and that terminologies are inclusive and clearly-defined. For example, a large dam is not merely a big dam, or a humungous dam: it is a formal engineering term. Likewise, the term "soft" issue is used in development contexts to indicate a non-physical process (ie non-construction / development / engineering), but can be seen as a derogatory term in the social sciences.
- We must continue a dialogue about cultural heritage and dams with experts from all relevant backgrounds through participation at regional and international conferences, the organization of further workshops, and regular correspondence and discussion aided by a discussion forum open to all without registration at our website: https://sites.google.com/site/saveculturalheritage.

Although only in its formative stages, the need for this project is already clear. Cultural heritage is threatened on a scale never before seen as global crises loom and urgent solutions are sought. We must make sure that those organisations and individuals in a position to act are aware of this urgent need and can influence international agendas in order to save cultural heritage.

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INTANGIBLE CULTURAL HERITAGE IN THE PACIFIC ISLANDS: WHY EUROPE SHOULD LISTEN IN

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KEY WORDS: Intangible Cultural Heritage, Pacific islands, Customs, Traditional Knowledge, Intellectual Property Rights, Economic Partnership Agreements, Development Policy.

ABSTRACT:

Pacific Island countries (PICs) are developing countries representing one of the culturally richest and most diverse regions worldwide. A decade ago, the realization evolved at international level that intangible cultural heritage (ICH) represents a development tool with an inherent commercial value. Regional initiatives are currently trying to balance objectives of development and protection of ICH with the need for commercial exploitation and effects of commodification. Yet, the same cannot be said about the Economic Partnership Agreement (EPA) between PICs and the EU. The article advocates that current EU efforts in supporting regional and national processes meant to establish a preliminary level of legal protection for Pacific ICH are insufficient and inappropriate to the 'living' character of ICH. It promotes a more context-oriented design of intellectual property rights (IPR) provisions in EU policy instruments aimed at sustainable development of the Pacific region.

1. INTRODUCTION

Pacific culture has often been described as "expressed through hundreds of languages, long-standing cultural traditions across largely dispersed island communities, works of Pacific art, and land sites of unique cultural importance for Pacific people" (Serrano and Stefanova, 2011). Marshallese navigational charts (*rebbilib*), Vanuatu's sand drawings (*sandroing*), Tuvaluan action songs known as *faatele* or Samoan traditional body tattoos, the *pe'a*, are but a few examples of the region's cultural wealth. While tangible cultural heritage has seen much publicity through its protection via United Nations Educational, Scientific and Cultural Organization (UNESCO) Heritage Sites[*], currently only few island countries have put in place legal frameworks for the protection of their traditional knowledge (TK) and intangible cultural heritage (ICH).[**] Even where intellectual property rights (IPRs) are protected under conventional trademark or copyright legislation, these laws either do not consider ICH to the extent necessary for meaningful protection or they are incompatible with the complex nature of ICH, rendering them inappropriate for its protection (Samoa Law Reform Commission, 2010).

Apart from inadequacy of existing legislation, a missing universal definition of ICH contributes to the infant state of ICH protection in the Pacific. While literature agrees on some common features and domains of ICH, no exhaustive definition exists yet (Yahaya, 2006). ICH is often referred to as "knowledge [that] was generated, added upon and passed down the line by words, observations and practices" (Menaka, 2010). UNESCO defines ICH as "constantly recreated by communities and groups, in response to their environment, their interaction with nature, and their history" (UNESCO, undated) while Art. 2 of the 2003 Convention for the Safeguarding of the Intangible Cultural Heritage lists "practices, representations, expressions, knowledge, skills, instruments, objects, artefacts and cultural spaces associated with communities, groups and individuals" as domains belonging to ICH (UNESCO, 2003). At government level, definitions range from "non-material culture" to "cultural living heritage" and "folklore and ethnic culture" (UNESCO, 2011). The international practice then is to define content and scope of each reference at national level, in accordance with the distinct nature of each country's context, its historic development, socio-legal circumstances, natural habitat available to stakeholders et cetera. According to Yahaya, so far there are no signs that "the finer terminology of 'heritage' has (…) been streamlined or standardised, and thus no uniformity exists between countries" (Yahaya, 2006). The difficulties encountered in defining and protecting ICH reflect the fact that to date a sui generis system of ICH protection in the Pacific is missing, despite the PICs' global forerunner role in this area.

Yet, the struggle to ascertain meaningful and effective mechanisms of ICH protection seems not to impede on the ability of Pacific islanders to claim ownership of their cultural heritage at national level. Particularly since independence, national traditions, customs and values are cherished as part of the national identity of Pacific people and are heralded as such in almost all post-colonial Pacific societies. Pacific Constitutions reaffirm the link between identity of the people and their customs and traditions by endorsing that "…the happiness and welfare of the people (…), both present and future, depend very largely on the maintenance of (…) values, culture and tradition" (Constitution of Tuvalu 1986); Statements such as "[a]ll we have and are today as a people, we have received as a sacred heritage which we pledge ourselves to safeguard and maintain…" (Constitution of the Republic of the Marshall Islands 1979) reflect the idea of a generational contract as well as a sense of continuity that underlies Pacific societies. These testimonials document the historic importance of cultural heritage and its critical place in relation to the

[*] There are currently seven officially inscribed UNESCO Heritage Sites in the Pacific, located in Fiji, the Marshall Islands, the Federated States of Micronesia, Papua New Guinea, Solomon Islands, Tonga and Vanuatu.

[**] The terms traditional knowledge and cultural property are used broadly and interchangeably in this article to reflect the definition in Article 2 of the Convention for the Safeguarding of the Intangible Cultural Heritage 2003.

distinctiveness of Pacific people; they are also indicative of claims of ownership based on perceptions of community rather than being expressions of individual rights.

However, culture in the Pacific islands is still treated in isolation from other national policies such as trade, development, education, health or environment. International lobbying for these ‘prime sectors’ of Pacific governments over the past decade has been successful, thereby leaving little policy space for mainstreaming of culture. In Vanuatu, for example, the National Self Reliance Strategy 2020 demands that a “cultural impact assessment (…) be developed and implemented as a development planning tool required for all new development initiatives” (Malvatumauri National Council of Chiefs *et al*, 2005). Unfortunately, the Strategic Plan is merely a recommendation to the government and so far not much progress has been recorded in turning it into legally binding commitments. Consequently, in Vanuatu’s Priorities and Action Agenda 2006-2015 there is no reference whatsoever to ICH as development tool (Vanuatu Government, 2006). As a result, national initiatives to streamline culture remain limited with a patchy picture of actions relevant to ICH. According to the Vanuatu Ministry of Education, there has been “some progress” in this area “but much remains to be done” due to “insufficient financial and human resources” at the disposal of the Ministry (Vanuatu Ministry of Education, 2012).

A decade ago, a common consciousness evolved that ICH may be utilized as an economic development tool with inherent commercial value. Countries like Korea, Ireland or China started to actively assist in the development of cultural industries and the utilization of cultural heritage for purposes of sustainable development. Here, ICH has become part of national economic development planning as well as an asset in industrial development plans. In England, for instance, the creative and cultural industries sector contributed £57.3 billion to the British economy (UK Local Government, 2009) while Thailand’s creative industries contributed about USD 43 billion to the Thai economy in 2008 (Kenan Institute Asia, 2009). In comparison, Pacific island governments have only recently started realizing that Pacific ICH can not only be exploited to attract more tourism and enhance the ‘Pacific paradise’ value of the islands for foreign direct investment (FDI); it can also be used as tool for development through job creation, utilization of niche markets and formation of creative industries whose particular role in economic development has also been increasingly recognized within the cultural policy discourse (Hartley, 2005).

Representatives of PICs agree unequivocally at regional meetings that “while cultural industries contribute to economic development [in the Pacific islands], the sector still represents a largely untapped socio-economic potential” (Secretariat of the Pacific Community, 2010). However, commercial use of ICH in the Pacific, as elsewhere, is controversial and carries a particularly contentious note. Research demonstrates that commercial use of ICH outside its traditional context changes the perception of the communities themselves towards their own cultural heritage [17]. This so-called Dream Catcher Syndrome, closely related to notions of misappropriation and out-of-context commodification of culture, has been exhaustively discussed in Indian-American context where it led researchers to conclude that such commodification inevitably leads to a “loss of meaning” for the bearers of the tradition themselves (Osborne, 2003/2004). As a consequence, the element of culture is removed from its context and becomes a meaningless item, story or song without the significant cultural connotation that made it classify as ICH for the community in first place.

In the Pacific, the Dream Catcher Syndrome can be observed in many places. In Samoa, for example, body tattoos have a traditional meaning for the bearer and only certain families or tattooists (*tufuga*) may perform the customary, sacred act of tattooing (*tatau*) people of Samoan descent only. In the words of Makerita Urale, a Samoan tattoo artist and film director, "the traditional male [Samoan] tattoo, which extends from the waist to the knees, embodies the concept of serving the people. It's also a rite of passage and a symbol of bravery, because it's very bloody and it sometimes takes an entire year to complete" [18]. In recent times however, Samoan tattoos have become part of a “Pacific pop culture” with tourists and visitors to Samoa perceiving the tattoos as ‘sexy’ and collecting Samoan traditional body art as a kind of ‘trendy souvenir’ from the Pacific. In this sense, Samoan body tattoos, despite their value as pieces of art, are losing their traditional meaning through detachment from the original context; their content and unique justification for their existence has been lost to many Samoan traditionalists in the process of commercialization.

The above example, as many others, illustrates the obvious need for a coherent, streamlined and holistic approach to ICH protection in the Pacific. This is also true for PICs’ international engagement with developed partners via multilateral trade and development treaties. These agreements often contain provisions with direct or indirect impact on the protection, development or commercial use of culture, including Pacific ICH. The Economic Partnership Agreement (EPA) between the European Union (EU) and PICs, building on the interim EPA signed by Papua New Guinea and Fiji in 2009, is a case in point.[*] Based on Art 36 and Art 37 of the Cotonou Agreement (CA), the Pacific EPA is an agreement that will go beyond economic development and trade liberalization to include issues such as peace building, human rights, sustainable economic development and support for regional integration. It is understood that the latest draft of the Pacific EPA text also contains provisions on intellectual property rights (IPRs) relevant to the protection and management of ICH. As such, it constitutes a document that should be included in the debate surrounding Pacific ICH.

Protection of ICH is undisputedly crucial. However, the modes of protection and the various policy and legislative options present a complex picture of ICH. The multifaceted nature of Pacific societies, the colonial heritage within their legal systems as well as the diversity of issues hiding behind the mask of ICH are key parameters within which the article seeks to provide some recommendations in regard to the meaningful protection of ICH. In doing so, it contributes to a growing international literature examining the status and regulation of ICH in various parts of the world, including the Pacific region. Through the application of the ‘Pacific lens’ to ICH issues, it also supports the Pacific countries’ pioneering role in setting international standards for ICH protection. In the following section, the

[*] Due to the complexity of the agreement, several conclusion deadlines have been missed for the Pacific EPA which has been under negotiation since 2002. At the June 2012 EU-ACP meeting held in Port Vila, Vanuatu, Pacific leaders demanded that the EU embraces in good faith its responsibility to negotiate a comprehensive, development-friendly EPA with PICs. The latest available draft text dates back to June 2006 and does not contain any provisions related to IPRs yet. The last draft EPA text, including IPR-related provisions, dates back to June 2011 but is unavailable to the public due to a missing response from the EU Commission.

article will highlight some of the ICH relevant initiatives undertaken at regional level. Emphasis will be placed on region-specific issues pertinent to the protection of ICH in legal pluralist environments of the PICs. Furthermore, the article will analyse the involvement of the EU in establishing a viable and meaningful regime of ICH protection in the Pacific islands. It will conclude with some recommendations for a context-orientated engagement of the EU with PICs at the intersection of the IPR, trade and development debate.

2. INTANGIBLE CULTURAL HERITAGE: THE PACIFIC WAY

In response to pressures of globalization, diminishing trade preferences and aid dependency, Pacific governments realized around 1999 in a trade-related context that Pacific ICH is a commercially exploitable 'commodity' in which PICs have a considerable relative trade advantage. What followed was recognition that, without proper protection and assignment of balanced and meaningful property rights, Pacific ICH was at imminent risk of misappropriation and excessive exploitation without appropriate compensation for traditional right owners, including individuals as well as communities. The trade context gave rise to some debate on how to manage and regulate Pacific ICH against the background of its 'living' nature. In a move towards an integrated design of IP-related legislation at national level, PICs developed three major regional initiatives of relevance for ICH: the Regional Framework for the Protection of Traditional Knowledge and Expressions of Culture (2002); the Traditional Biological Knowledge, Innovations and Practices Model Law (2008); and the Melanesian Spearhead Group's draft Treaty on Traditional Knowledge (2011).

All three regional models set out amendable framework provisions for protection of ICH at national level. So far, most PICs have chosen to implement the model laws in their national legislation. TK Legislation is at different stages of implementation in PICs, with Kiribati and Fiji having legislation already in place while others such as Palau and Nauru are still organizing resources for policy directions on TK legislation. Most countries have chosen different pathways to their legislation, with Fiji starting the process with a legislative proposal and Kiribati holding consultations first to arrive at policy instructions [19]. According to Forsyth, the diversity of approaches will result in very different pieces of legislation at national level, despite the Model Laws' call for a harmonious approach [19]. In the following section, the three main legislative initiatives at regional level will be discussed in brief to highlight parallels and differences in approach.

In 2002 the Framework Treaty on Traditional Knowledge and Expressions of Culture (TKEC) was endorsed by the Regional Meeting of Ministers of Trade under auspices of the Pacific Islands Forum Secretariat (PIFS). It is generally thought of as a major achievement in protecting Pacific ICH [20]. Based on a very broad, open-ended definition of TK and "expressions of culture" in Art. 4 as well as the relatively new concept of Traditional Cultural Rights (TCRs), the TKEC Framework Treaty is applicable to tangible and intangible cultural heritage without making this distinction expressis verbis. According to Marahare, "[t]he policy objective of the [Framework Treaty] is to protect the rights of traditional owners in their traditional knowledge and expressions of culture and to permit tradition-based creativity and innovation, including commercialization thereof, subject to prior and informed consent and benefit-sharing [20]. The TKEC Framework Treaty was "designed with the circumstances of the Pacific in mind, expected to form the basis of a harmonized regional legal framework" [21]. Its main objective is to encourage sui generis legislation in PICs and to give policy makes a framework that can be adapted to individual national circumstances of each country in the region. The TKEC Framework Treaty uses a combination of legal forms of protection, such as exclusive property rights, moral rights, criminal offences and civil actions [21]. Furthermore, it permits commercial use of TCEK but ensures that this is based on prior informed consent of the traditional owners who are to be included in benefit-sharing on the basis of equitable, accessible, transparent contracts. In addition, it ensures that the rights granted are inalienable and continue in force in perpetuity.

The innovative elements of the TKEC Framework Treaty are thus threefold. First, it represents the earliest Pacific initiative to take TKEC out of the public domain and to allocate meaningful TCRs to traditional owners of TCEK. Second, it symbolizes a first balanced approach between ownership traditionally articulated through national IP policies, and stewardship based on cultural policy, including heritage and diversity policy. Third, it combines exploitation of ICH with the necessary protection for its context, present rightful owners and future generations of traditional custodians of ICH. As such, the Framework Treaty goes beyond a purely IP-based system of ICH protection by empowering communities through collective rather than individual rights and by protecting TCRs usually left out in conservative, western-style IP-based systems. Under the Framework Treaty, the traditional owners of ICH are thus treated as de facto custodians of ICH – an approach already advocated in early works on cultural rights of indigenous people [22].

On renewed initiative of Trade Ministers, and with support from the World Intellectual Property Organization (WIPO), the Traditional Biological Knowledge, Innovations and Practices (TBKIP) Model Law was endorsed in 2008. The main driving force behind this initiative was the realization of the important role that TK plays in resource management, the sustainable use of biodiversity and food security in Pacific societies. An additional catalyst was the growing concern regarding illicit uses and misappropriation of TK in the Pacific as well as the awareness of the potential economic damage of such practices. A Member of Vanuatu Parliament, MP Regenvanu, recently voiced his concern by stating that "a number of entities are continuing to patent genetic material from Vanuatu presumably without any access and benefit sharing agreements, or consideration of the rights in identifying these plants and animals as potential sources of pharmaceuticals [23]. And while Vanuatu Parliament is expected to debate the WIPO Ratification Bill and the Bill for the International Treaty on Plant Genetic Resources for Food and Agriculture (Ratification) Act in this First Ordinary Session in 2013, according to a source at the Ministry of Finance and Economic Management, the loss of revenue due to illicit bio-prospecting activities without any benefit-sharing agreement is currently estimated in Vanuatu alone at 60 million US dollar over the past decade [24].

The Model Law is expected to form a considerable basis for the legislation currently debated in Vanuatu and elsewhere in the Pacific. Similar to the Framework Treaty 2002, the Model Law determines that the traditional owners of TBKIPs are the holders of moral rights in their TBKIPs and that these comprise the right of attribution of ownership; the right not to have ownership of TBKIPs falsely attributed; and the right not to have their TBKIPs subject to derogatory treatment. The Model Law further stipulates that where TBKIPs are used for a commercial purpose, there is a requirement for fair and equitable benefit sharing arrangements (monetary or non-monetary compensation) with the traditional owners. It remains to be seen how and to what extent these provisions will be mirrored in national legislation over the next couple of years. However, the recent Pacific move towards accession of WIPO and signature of UNESCO Treaties is expected to have an impact via stronger IP-based legislative regimes in opposition to regimes based to a greater extent on customary law. For the sake of a balanced approach to ICH protection, the latter should thus receive a more prominent place in regional frameworks than is the case to date.

In December 2009, the Traditional Knowledge Action Plan for the Pacific region, based on directives of Pacific Trade Ministers, has been launched at a Traditional Knowledge workshop convened by the Pacific Islands Forum Secretariat (PIFS) and World Intellectual Property Rights Organisation (WIPO) in Fiji. Responsibility for the implementation of the TK Action Plan rests with the PIFS working in close collaboration with the Trade Com - an ACP Group Programme financed by the European Development Fund (EDF), aiming at support for the formulation of trade policies, trade negotiations and the implementation of international trade agreements – WIPO, the Secretariat of the Pacific Community (SPC) and the South Pacific Regional Environmental Programme (SPREP). Heralded as “milestone development for the region” [25], the Action Plan’s main objective is twofold. It aims at the development of national systems of protection setting out new rights and obligations in TK that will complement existing forms of protection for intellectual property (Phase I) and development of cultural industries in the region through activities to promote the commercialization of TK (Phase II). The Action Plan itself stipulates that “[l]egal certainty of ownership and management of resources will be established, providing security and predictability for economic developments in business, technology and investment, local creativity and innovation.” The strong commercial focus on TK derives from the trade-driven context of the Action Plan as well as from its founding fathers’ IPR agendas.

Phase I of the TK Action Plan resulted in its implementation in a first group of countries consisting of the Cook Islands, Fiji, Kiribati, Palau, Papua New Guinea and Vanuatu. At their May 12, 2012 meeting in the Marshall Islands, the Forum Trade Ministers agreed to extend the priority for Phase II of the TK Action Plan to include technical assistance for the drafting of TK policy and legislative frameworks in PICs. What has been perceived as problematic in this legislation-first, top-down approach is the fact that it was not based consultation with stakeholders [26] – an omission which may result in misinterpretation of rights or, even worse, oversight of rights currently recognized under customary law. At the same time, the Ministers decided most recently to focus on further commercialization of TK and cultural industries, despite dangers outlined above under the Dream Catcher Syndrome. In the face of its strong commercial focus, the TK Action Plan must thus be seen as an opposite force to the Model Law. By applying western value systems to the protection of amorphous, community-and context-based, living ICH, the Action Plan largely mirrors conservative, IP-based agendas of trade-driven development initiatives led by WIPO or the EU in EPA context. Simultaneously, the commercial focus carries to a large extent the exclusion of customary law from ascertaining IPRs or their enforcement that is largely left to state institutions. Issues created by the state-centered approach of the Action Plan as well as the non-pluralist intake on ICH protection have both been highlighted by Forsyth [26].

In a most recent move, the MSG Framework Treaty on the Protection of Traditional Knowledge and Expressions of Culture was adopted at the MSG Leaders Summit on 31 March 2011. As members of the Melanesian Spearhead Group of Countries (MSG), the Governments of Fiji, Papua New Guinea, Solomon Islands and Vanuatu, pledged “to protect traditional knowledge holders and owners against any infringement of their rights as recognized by this Treaty (…) and to protect expressions of culture against misappropriation, misuse and unlawful exploitation” [27]. At the time of writing, the MSG Treaty has been approved in principle by its members, but has not been signed by all MSG countries yet; it needs the deposition of two instruments of ratification with the MSG Secretariat for its entry into force. The MSG Framework Treaty is similar to the 2002 Framework Document in scope and subject matter as well as in the allocation of TK ownership or the duration of protection. Its innovation relates to the collaborative element of the MSG Framework Treaty which stipulates in Article 15 cooperation in cross border measures as well as networking of judicial authorities and enforcement agencies. Such collaboration has a potential to develop into an integrated and harmonized approach to TK protection, at least at sub-regional level. This in itself, if executed, would guarantee that customary protection and management practices are included in the legislation of at least the MSG member countries.

3. WHY EUROPE SHOULD LISTEN IN

Article 167 of the Treaty on the Functioning of the European Union (Lisbon Treaty) commands the mainstreaming of culture into EU policies in the fields of external relations, development, and trade. The 2007 European Agenda for Culture reinforces the Lisbon Treaty mandate by stating that "culture is increasingly perceived [by the EU] as a strategic factor of political, social and economic development and not in terms of isolated cultural events or showcasing" [28]. In its 2010 progress report on the implementation of the EU Agenda for Culture, the European Commission stressed that next to EU technical and financial assistance, the EU is increasingly concerned with the protection of rights of indigenous people and the promotion of cultural rights in general [29]. In relation to development cooperation, the progress report makes a reference to "living culture and cultural heritage", recognizing them "important for growth, jobs and cultural identity". Furthermore, in cooperation with a UNESCO-managed expert facility, the EU is committed to support the development of an institutional and regulatory framework based on IPRs to "facilitate and respect the commercial exploitation of the [ACP countries’] cultural heritage" [28].

Until the entry into force of the Cotonou Agreement (CA) in 2000, culture did not appear as a stand-alone issue in EU-ACP relations and was mostly seen through the lens of human resource development or the preservation of natural heritage in ACP countries [30]. Art 27 CA states that the cultural dimension is to be implemented at all levels of development cooperation and in developing cultural industries and enhancing market access opportunities for cultural goods and services.[*] In

[*] In 2007, the title of Article 27 CA was amended from "cultural development" to "culture and development" to better reflect the role culture plays in general economic development of ACP countries.

the Pacific, the EU recognized accessibility as the biggest impediment to the development of a "sustainable Pacific arts sector that is valued as a pathway to economic empowerment" [28]. The EU's current efforts - supported by a grant of 713,000 Euro from the 10th European Development Fund and covering the period 2008-2013 - focus on a restructuring of the Pacific cultural sector so that culture is better recognized as a driver of, and a tool for, development. EPAs are one expression of those activities.

In EPAs with ACP countries, the EU addresses culture as a non-trade objective and uses EPA provisions "to promote intellectual property protection standards and ensure that the rights of artists and performers get the protection they deserve" [29]. Usually, IPR-related trade provisions would seek to strengthen IPR enforcement in ACP countries. After all, strong IPR represent a vital interest of European right holders against the background of frequent IP breaches in developing countries with a weak IP (enforcement) regime. In return, the EU is prepared to agree, usually in an additional Protocol to the EPA, on "preferential treatment for developing countries' cultural goods, services and cultural practitioners, outside of the provisions on trade liberalization" [31]. The draft Pacific-EU EPA text of June 2006 is the latest publicly available text and does not contain any IPR-related provisions yet. The 2011 EPA draft text does most probably contain IPR-related provisions that are thought to be similar to the provisions contained in the EU-CARIFORUM EPA. If this is correct, PICs need to be aware that the IP standards required of them will, in part, be above the standards advocated in WIPO treaties and the Trade Related Aspects of Intellectual Property Rights (TRIPS) Agreement of the World Trade Organization (WTO).

As outlined above, PICs are in the midst of formulating regional frameworks for ICH protection and drafting of national legislation has begun. While there has been little debate on the cultural dimension to development or the contribution a cultural protocol may have to sustainable development and service provision in the Pacific [16], there is common agreement that any IPR-related provisions need to take into account the peculiarities of the Pacific context, especially the pluralist nature of Pacific legal systems as well as the living and amorphous characteristics of ICH. Ideally, the Pacific EPA should mirror the key provisions of the 2002 Framework Treaty and the 2011 MSG Model Law in adopting a community rights based approach to ICH and allowing sufficient recognition for already existing models of customary ICH protection and enforcement. Instead of a state-centered approach to ICH as followed in the TK Action Plan, the Pacific EPA should focus on indigenous communities as custodians of ICH. In addition, IPR-related EPA provisions should provide sufficient recognition and address of issues emerging in Pacific communities following commercialization and commodifcation of ICH.

The main challenge relates to the fact that, due to a lack of home-grown expertise in the area of protection of ICH, Pacific governments often have no other choice than to accept IPR-related proposals as a given. In consequence, IPR provisions in the Pacific EPA will inevitably be removed from the Pacific context and will be often based on preconceived perceptions of a particular system of culture management, exploitation and protection that is biased towards EU's requirements. Without a relation of this external model to the Pacific context, the value of the resulting provisions and the effectiveness of legislation drafted on the basis of western assumptions about ICH will unsurprisingly be limited. The EU could, at a minimum, ensure that Pacific concerns are taken seriously in negotiations of any IPR-related provisions in the Pacific EPA.

Another relevant issue in ICH protection in the Pacific relates to the orthodox distinction between individual and collective rights and the difficulties state legal systems are facing in protecting the latter via IPR provisions designed to provide protection for individuals. Despite the fact that "[o]ver the past two decades, there has been a gradual shift towards an understanding of cultural rights as a collective right, in addition to an individual right" based on "the progressive global acknowledgement of cultural diversity and difference" as well as "the recognition of rights of indigenous peoples" [32], the Pacific EPA is unlikely to adapt to this shift in IPR-related provisions which are traditionally replicas of western-style IPR standards orientated towards individual ownership of IPRs.

The EPA presents a unique opportunity for the EU to sustain the regional initiatives in Pacific ICH management and protection; it also bears the prospect of support to remedy the fragmented national approaches to ICH via an integrated, harmonized sui generis solution that all PICs can subscribe to. The development dimension of the EPA should ensure that the EPA becomes a tool for contextualized approach to IPRs in the Pacific region, taking into account peculiarities and sensitivities of Pacific ICH. In an open-minded approach, pluralist environments could be seen as enriching the landscape of ICH management options while offering as good a protection to IPRs via customary law as could be achieved otherwise by relying solely on state-centered approaches. The mandate of the CA to respect the development status of EPA partners as well as regional integration initiatives under way seems supportive of an alternative approach to IPR provisions, one that goes beyond market access and effective enforcement. Before setting up a binding IPR regime via the Pacific EPA, the EU should listen in to the words of Boyle in which he expressed the potential impact of IPRs by saying "when you set up property rules in some new space, you determine much about the history that follows" [33].

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TOWARDS A EUROPEAN COLLABORATIVE DATA INFRASTRUCTURE

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ABSTRACT:

The EUDAT project is a pan-European data initiative that started in October 2011. The project brings together a unique consortium of 25 partners – including research communities, national data and high performance computing (HPC) centres, technology providers, and funding agencies – from 13 countries. EUDAT aims to build a sustainable cross-disciplinary and cross-national data infrastructure that provides a set of shared services for accessing and preserving research data. The design and deployment of these services is being coordinated by multi-disciplinary task forces comprising representatives from research communities and data centres. This short paper presents the achievements of the project during its first year and describes the services that have been chosen to meet the requirements of the initial research communities involved in the project.

1. INTRODUCTION

In recent years significant investments have been made by the European Commission and European member states to create a pan-European e-Infrastructure supporting multiple research communities. As a result, a European e-Infrastructure ecosystem is currently taking shape, with communication networks, distributed grids and HPC facilities providing European researchers from all fields with state-of-the-art instruments and services that support the deployment of new research facilities on a pan-European level. However, the accelerated proliferation of data – newly available from powerful new scientific instruments, simulations and the digitization of existing resources – has created a new impetus for increasing efforts and investments in order to tackle the specific challenges of data management, and to ensure a coherent approach to research data access and preservation.

Although some solid experience exists in Europe in dealing with data infrastructures, the current data landscape is still fragmented, with most initiatives addressing the needs of a specific discipline or community. This has resulted in increasing diversity with respect to data architectures, organizations, formats and semantics. Issues related to integration and the interoperability of existing data infrastructures are a growing concern. Rising costs due to the explosion of data are also threatening the financial viability of those infrastructures.

2. SHARED SOLUTIONS: THE CASE FOR CROSS-DISCIPLINARY DATA SERVICES

The way data is organized differs from one research community to the next; we must acknowledge this heterogeneity as a starting point, while at the same time looking for some degree of integration through common solutions and services where possible. Although research communities from different disciplines have different ambitions and approaches – particularly with respect to data organization and content – they also share many basic service requirements. This commonality makes it possible for EUDAT to establish common data services, designed to support multiple research communities, as part of a Collaborative Data Infrastructure (CDI).

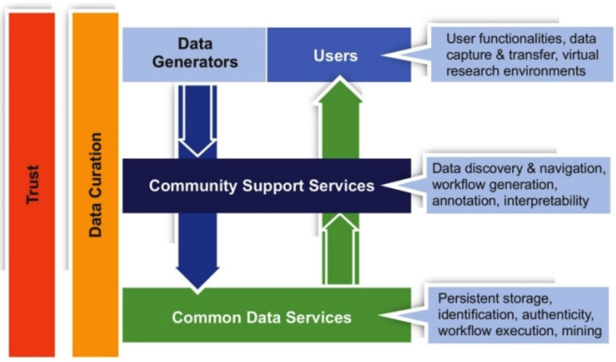

Figure 1: The Collaborative Data Infrastructure: A framework for the future © HLEG on Scientific Data, 2010

Figure 1 is taken from the *Riding the Wave* report by the High Level Group (HLEG) on Scientific Data (High Level Expert Group on Scientific Data, 2010). It illustrates the kind of collaboration required between the different parties involved in the future CDI and proposes a particular framework whereby centres offering community-specific support services to their users could rely on a set of common data services shared between different research communities.

The benefits associated with creating such a collaborative framework are many and will result in better exploitation of synergies. By supporting the infrastructures that existing scientific communities have for their generic data services, the CDI will enable the communities to focus a greater part of their effort and investment on services that are discipline-specific. The CDI will also provide individual researchers, smaller

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communities, and projects lacking tailored data management solutions with access to sophisticated shared services, thus removing the need for large-scale capital investment in infrastructure development. Lastly, by providing opportunities for disciplines from across the spectrum to share data and cross-fertilize ideas, the CDI will encourage progress towards the vision of open and participatory data-intensive science.

It is vitally important that large e-infrastructures meet the concrete needs of research communities, and that they are designed and set up in accordance with professional IT principles. To achieve this, there must be a close interaction between various stakeholders throughout the development process. Building the CDI requires active collaboration in particular between the communities involved in designing specific services and the data centres willing to provide generic solutions. To this end EUDAT has formed a unique consortium that brings together 25 partners, including research communities, national data and high performance computing (HPC) centres, technology providers, and funding agencies from 13 countries.

3. THE RESEARCH COMMUNITIES IN EUDAT AND THEIR DATA

Five research communities joined the EUDAT initiative at the start. They are acting as partners in the project, and have clear tasks and commitments. These initial communities come from different research areas:

- LifeWatch (Environmental Sciences – Biodiversity)
- ENES (Climate Modelling)
- EPOS (Earth Sciences)
- CLARIN (Linguistics)
- VPH (Biological and Medical Sciences)

Since EUDAT started on the 1st of October 2011, we have been reviewing the approaches and requirements of these five communities regarding the deployment and use of a cross-disciplinary and persistent data e-Infrastructure. This analysis was conducted through interviews and frequent interactions with representatives of the communities and the preliminary results are presented in this paper.

It is important to note that not only does the actual data organization vary between these communities, but there are also differences in how far individual communities have come in discussions about their data, and in the terminology that the communities use to describe their own data. Therefore we chose to use the “Digital Object Architecture” as introduced by Kahn and Wilensky (Kahn, R., Wilensky, R., 1995) as a kind of reference model and a basis from which to study the communities. For each community we looked at their general data landscapes and architectures, the types of data objects being handled, and the data flows describing how their data is manipulated. We begin here by presenting some general characteristics of the general data landscapes in each of the five communities, and then describe some of the common service requirements that were identified.

CLARIN (Common Language Resources and Technology Infrastructure) is a large-scale European initiative aiming at improving the use and availability of language resources and language technology for linguists and also other researchers from the European humanities and social sciences community. CLARIN centres form the backbone of the CLARIN research infrastructure and work with various types of data ranging from unstructured book and newspaper data to structured data, such as complex annotations, lexica and ontologies. Common types of streaming data (for example, audio and video data), along with other types of time series data (such as eye or gesture tracking and brain imaging data) are also used by language researchers. There are about 25 to 30 CLARIN centre candidates, but some heterogeneity exists between these centres in terms of data organisation. Minimal requirements (related to repositories, formats, metadata, and persistent identifiers) are being set forth for organizing the data within CLARIN centres.

ENES (European Network for Earth System Modelling) gathers together about 20 institutions working on climate modelling research. Climate change models need to account for detailed processes occurring in the atmosphere, in the ocean and on the continents. These models need to capture complex nonlinear interactions between different components of the Earth system and assess how these interactions can be perturbed as a result of human activities or natural variability. ENES works with large volumes of data generated from modelling, or collected from observation points all over the world or from satellite observations. ENES climate modelling centres use the CIM data model with an architecture separating metadata from data and using persistent identifiers. However, this model is still in the prototype phase, and the centres continue to use file systems where directory and file names include essential information about the relationships.

EPOS (European Plate Observing System) is an infrastructure for researchers in the solid Earth Sciences – studying, for example, the physical processes controlling earthquakes, volcanic eruptions, and tsunamis, as well as those driving tectonics and Earth surface dynamics. EPOS researchers work a lot with raw data streams originating from different types of sensors. Many data sensor stations used by EPOS ingest data in real time in such a way that each stream is sent to several data centres. Sensor station data is produced as a never-ending sequence of packets, while, at the data centres, data streams must be divided into files. Every centre has its own system, which means that the stored data objects are not forcibly identical. Although some work has been made to integrate the many centers, in particular within the seismology community (where there are agreements for the formats and the manner the data are federated among archives), further integration across sub-communities is needed. EPOS’s intent is to virtually integrate the various data streams to offer a complete overview of the available data to users.

LifeWatch is a European initiative aiming to provide tools and services enabling researchers in biodiversity (who come from diverse disciplines) to share expertise and information remotely, through “virtual labs”. Data formats vary according to the community that the data originates from. A large amount of LifeWatch data is geospatial – for example, remote sensing data from satellite imagery or real time sensor data. Other data comes from environmental and life sciences, and also from national biodiversity collections.

The VPH (Virtual Physiological Human) project aims to provide digital representations of the entire human body,

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http://cmip-pcmdi.llnl.gov/cmip5/

including biological, imaging, clinical and genomic data that can be used by academic, clinical and industrial researchers to improve their understanding of human physiology and pathology, and thus find better ways of treating individual patients. Data generated and used by VPH researchers includes imaging data, and genetic data, along with simulation model data and output data.

Thus, there is considerable variation between the data landscapes in these communities, and also in the ways that researchers in these communities make use of their data. All communities rely on an infrastructure and sets of services (either existing or being developed) to support their needs. However, some of these needs are currently only partially fulfilled while at the same time some generic requirements are shared across these communities.

After several months of discussion and interaction with representatives from these communities, we have shortlisted six types of generic services that have been identified by these communities as priorities. These six services are being built jointly within the EUDAT project through multi-disciplinary task forces involving representatives from communities and data centres. The services are data replication from site to site, data staging to compute facilities, metadata, easy storage, persistent identifiers and authentication and authorization.

4. EUDAT SERVICES AND TECHNOLOGIES

4.1 Data Replication and HPC Access

There is strong demand among the research communities involved in EUDAT for data replication services associated with better access to computing power. This demand underpins two of EUDAT's common data services – safe data replication, and the ability to move data to and from HPC facilities.

The "safe replication" service team is working on developing a service that will make it possible to replicate data from one site to another, for example, from a scientifically-oriented community centre to a data centre. This service is required across all five research communities, in particular it is needed to facilitate better data access and data preservation.

Several pilot studies involving three of the five communities (EPOS, ENES, and CLARIN) and five data centres (JUELICH, SARA, RZG, CSC, and CINECA) have been launched and consist of replicating data sets between community and data centre sites. The first phase involves different "islands" in which a particular community is working closely together with one or several data centres to implement, test and evaluate the service. The next phase will consist of merging the islands into a single EUDAT space where communities are able to replicate digital objects (DO) to all data centres.

After investigating several technologies, EUDAT chose to use iRODS as an initial replication middleware. For the management of the persistent identifiers – which are automatically assigned to the digital objects to make it possible to keep track of all the replicas – EUDAT chose to use the handle system through the services provided by the European Persistent Identifiers Consortium (EPIC) .

http://www.pidconsortium.eu

Once users have their data replicated on the EUDAT infrastructure, we anticipate that they will want to be able to use neighbouring computing facilities to analyse this data. In particular, this is required by VPH, ENES, and EPOS as they all need to perform statistical model analysis on stored data.
Another series of pilots involving VPH, EPOS, CINECA, SARA and CSC is currently under implementation to build such a "data staging" service. Similar processes to those used in the safe replication service (involving communities and data centres working initially in separate islands) have been adopted.

Several technologies and techniques are being evaluated for staging data such as basic iRODS tools, Globus On-line, XSEDE file manage, UNICORE FTP, and Parrot. The input data sets can range from tens of gigabytes to a few terabytes in the case of special events, such as big earthquakes for EPOS. The results of the computations, which need to be ingested back into the EUDAT storage facility, are usually larger than the input data by a factor of two.

The areas of safe data replication and dynamic data replication are obviously closely connected. Figure 2 shows the different steps to be considered in a scenario where data coming from a research community (in this case EPOS) is staged from the EUDAT store to three HPC facilities (CINECA, SARA, and PRACE).

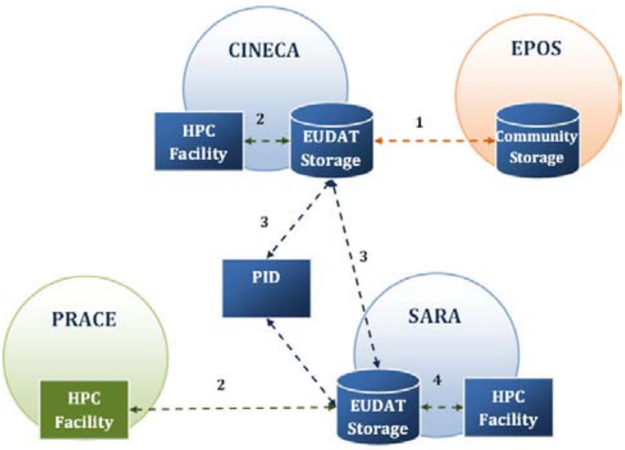

Figure 2: Utilization scenario steps for replicating and staging data from one site to another

In this scenario, data is first replicated from a community storage facility to one of the EUDAT nodes using "safe replication" solutions (1). The data is then staged to an HPC facility, either close to the EUDAT node or available outside, for example, within the PRACE infrastructure (2). The data can be replicated between two EUDAT nodes to target the required HPC facility. The corresponding PID record contains all relevant URLs of the copies (3). The replicated data is then staged to the local HPC facility and the analysis results are staged out to the original source (4). The results can then be copied back to the community storage facility.

4.2 Making Data Visible and Reusable

Complex problems or "grand challenges" increasingly require a trans-disciplinary approach relying on data coming from multiple research fields. In this context, making data from various disciplines available in one collaborative infrastructure can be extremely beneficial. To achieve these goals, data stored on the EUDAT infrastructure must be visible, readable, understandable, and easily accessible by all. This requirement is shared across the five research communities, not only to allow them to make their data more visible, but also to make it possible to work with data coming from other disciplines.

Part of the challenge resides in finding good metadata solutions that allow metadata from different communities to be integrated into easily searchable catalogues. To this end, an EUDAT metadata task force has been set up and is currently investigating the best way to develop a joint metadata catalogue. Using the OAI-PMH protocol and embedding domain specific metadata (as an extra available metadata record) within the OAI-PMH record is currently seen as the best option for harvesting metadata from communities and developing a joint catalogue.

The EUDAT metadata service should offer basic metadata search and browsing services to researchers looking for, or exploring, the resources from other disciplines, and could also include a "commenting" function allowing researchers to comment on the usability and/or quality of the data sets found in the catalogue. The metadata service could also be used by emerging communities that do not (yet) have their own metadata service or that are too small to provide one. Although EUDAT is in favour of open data in the scientific environment, granting access to data should ultimately remain a matter for the communities.

Thus, EUDAT's prime objectives are to build services that are shared across disciplines, and that can support cross-disciplinary data-intensive science. Despite this emphasis on commonality, some services can be tailored to a smaller subset of communities or even to individual researchers. EUDAT will host "community services", allowing user communities to use EUDAT resources to deploy and run specific services on the EUDAT infrastructure. Individual researchers and small projects will also be catered for, with a "simple store" service that allows the storage and sharing of the vast quantity of "small" data, that is, data that is not part of official data sets or collections, but that is equally important for the advancement of research.

4.3 Federated AAI and Access with SSO

In order to achieve these objectives we must work to facilitate easy access to the infrastructure and its services, while at the same time ensuring that the data is well preserved and that access rights are correctly managed. A federated authentication and authorization infrastructure (AAI) supporting single identity and single sign-on (SSO) is required.

Many communities already have AA infrastructures or rely on others provided by universities, national (academic) identity federations or other e-infrastructures (such as EGI and PRACE). The approach taken in EUDAT is to make as much use as possible of existing infrastructure. In this way EUDAT will make it possible for users to identify themselves to services in the way that they are familiar with, instead of introducing additional methods or requiring new credentials for specific EUDAT services.

http://www.openarchives.org/OAI/openarchivesprotocol.html

Because of the many different technologies and methods available for authentication and authorization, as well as the different national legislations to be taken into account when implementing AAI solutions, this task is one of the most complex tasks involved in the project.

5. REACHING OUT TO OTHER COMMUNITIES

The services being designed in EUDAT will be of interest to a broad range of communities that lack their own robust data infrastructures, or that are simply looking for additional storage and/or computing capacities to better access, use, re-use, and preserve their data.

Although EUDAT has initially focused on a subset of research communities, it aims to engage with other communities interested in adapting their solutions or contributing to the design of the infrastructure. Discussions with other research communities – belonging to the fields of environmental sciences, biomedical science, physics, social sciences and humanities – have already begun and are following a pattern similar to the one we adopted with the initial communities. The next step will consist of integrating representatives from these communities into the existing pilots and task forces so as to include them in the process of designing the services.

Communities that are active in the field of digital cultural heritage and that are eager to take full advantage of the recent e-Infrastructure developments could also be interested in the EUDAT initiative. A recent document published by the DC-NET project (DC-NET Working Group 3: New Services Priorities, 2012) listed the priorities of such communities in terms of services. Areas, such as long term preservation, persistent identification, advanced search, user authentication and access control, are all services that could potentially be addressed by EUDAT.

6. CONCLUSIONS

After only one year of activity, significant progress has been made by EUDAT to lay out the foundations of the CDI. Yet there is still much to achieve before the CDI becomes reality and can be effectively used to support the needs of the many research communities that are facing the challenges associated with the so-called "data deluge" today.

Another important strand of activity in EUDAT focuses on the operation of the collaborative data infrastructure, particularly providing secure, reliable (generic) services in a production environment, with interfaces for cross-site and cross-community operation. The operation of the infrastructure should provide full life cycle data management services, ensuring the authenticity, integrity, retention and preservation of data, especially data marked for long-term archiving.

The challenges are technical, but also social and organizational. Successful collaboration must be built on trust between service providers and users, and also between the researchers and disciplines themselves.

We must also plan, from the very beginning, for the evolution and sustainability of the infrastructure. Among other things, this implies early definition of future partnership and business models for adopting, supporting and sustaining common services developed for, and partly operated by, the different research communities.

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SCIENCE DATA INFRASTRUCTURE FOR PRESERVATION - EARTH SCIENCE

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KEY WORDS: Long term data preservation, Earth Science, Preservation Policies and techniques, Earth Observation

ABSTRACT:

The proper preservation of both current and historical scientific data will underpin a multitude of ecological, economic and political decisions in the future of our society. The SCIDIP-ES project addresses the long-term persistent storage, access and management needs of scientific data by providing preservation infrastructure services. Taking exemplars from the Earth Science domain we highlight the key preservation challenges and barriers to be overcome by the SCIDIP-ES infrastructure. SCIDIP-ES augments existing science data e-infrastructures by adding specific services and toolkits, which implement core preservation concepts, thus guaranteeing the long-term access to data assets across and beyond their designated communities.

1. INTRODUCTION

1.1 The Challenge

Climate change, environmental degradation and ecological sustainability are amongst the most vital aspects that need to be understood and managed today and in future. Understanding these challenges involves the complex analysis of environmental information, such as Earth Science data to inform government policy and practical implementation in areas (e.g. climate change, water management, health and agriculture) that underpin the stability of existing socio-economic and political systems. Thus there is a need to preserve a flood of Earth Science (ES) data and, more importantly, the associated knowledge to ensure its meaningful long term exploitation. Moreover, certain environmental analysis, like those supporting the long-term climate change variables measurement, requires historical data records to be periodically reprocessed to conform to the latest revisions of scientific understanding and modelling techniques. This in turn requires access to and understanding of the original processing, including scientific papers, algorithm documentation, processing sources code, calibration tables, databases and ancillary datasets.

To maximise the value of ES data, its usage should not be limited to the domain scientists who originally produced it. ES data as a "research asset" should be made available to all experts of the scientific community both now and in the future. The ability to re-purpose existing ES data could cross-fertilise research in other scientific domains. For example, if epidemiologists can correctly interpret environmental data encoded in an unfamiliar format, the additional knowledge may assist them with understanding patterns of disease transmission.

Unfortunately getting access to all the necessary data and metadata is a serious problem; often the data are not available, accessible or simply cannot be used since relevant information explaining how to do so or the necessary tools, algorithms, or other pieces of the puzzle are missing. Moreover the ES data owners are dealing with the preservation and access of their own data and this is often carried out on a case by case basis without established cross-domain approaches, procedures and tools.

The SCIence Data Infrastructure for Preservation – Earth Science (SCIDIP-ES) project [1] is developing services and toolkits which can help any organisation but the prime focus in this project is to show their use in ES organisations working with non-ES organisations concerned with data preservation to confirm the wide effectiveness in helping to improve, and reduce the cost of, the way in which they preserve their ES data holdings. In parallel, the project is will produce harmonized models for Earth Science data preservation policies, technologies, semantics and ontologies. This is carried out in tied coordination with the work already undertaken by the Long Term Data Preservation Working Group, which has developed Guidelines for Earth Observation data preservation. The goal is to harmonize and extend the model to the Earth Science wider sector.

2. BARRIERS AND CHALLENGES OF EARTH SCIENCE DATA PRESERVATION TITLE

Here, we discuss some of the key challenges of preserving ES data considered by the SCIDIP-ES project. We have identified these challenges based on the results of a series of surveys conducted by SCIDIP-ES on various aspects of preserving ES data, as well as related external materials, such as the PARSE.Insight case studies [2] on the preservation of Earth Observation (EO) data. Notably, some of the issues outlined here are also relevant beyond the ES and EO domains to the wider data preservation problem.

2.1 Ensuring Intelligibility an (Re-) Usability of Data

A frequently repeated mantra for digital preservation activities is "emulate or migrate", which is also pertinent to the ES data. However, while these activities may be sufficient for rendered objects, such as documents or images, they are not enough for other types of digital objects. In addition, there is a need to capture Representation Information (RepInfo) - a notion defined by the widely adopted ISO standard [3] Open Archival Information Systems (OAIS) Reference Model [4] to represent the information needed to access, understand, render and (re)use digital objects. The key aspects of RepInfo needed to ensure continued intelligibility and usability of data include Semantic

Representation Information (i.e. intended meaning and surrounding context of data) and the identification of a Designated Community (consumer of the data).

2.2 Designing Cost Effective Preservation

Long-term preservation archives and repositories must plan responses to changes and risks of changes in an appropriate and cost-effective way. As discussed above there are many different types of preservation action/strategy which are equally valid and need to be considered when a preservation solution is formulated for a data collection. Archives need to be aware of, characterise and describe the main types of preservation action available to an archivist. They also need to appreciate the effect each type of action has upon a network of RepInfo, the risks, available modes of stabilisation as well as cost and benefits. Hence there is a need for tools to help to evaluate and balance costs and risks in a network of RepInfo In addition, they need to consider how more than one type of strategy can be employed as alternates in order to create the optimal balance of risk and usability of a preservation solution.

2.3 Reacting to changes in preservation requirements

As mentioned above, long-term data archives need to be able handle changes in preservation requirements by re-strategizing when needed. It is well understood that hardware and software become unavailable but also the semantics of specific terminology change and the knowledge base of the Designated Community, as chosen by a repository, changes. All these changes must be countered if we are to preserve our digitally encoded information. Yet how can any single repository know of these changes? Significant effort (e.g. the preservation watch service of the SCAPE project [5]) is being put into technology watches for document and image format changes. It is more difficult for a repository to watch for all possible changes, such as in terminological changes across a multitude of scientific disciplines, and to understand the ramifications of such changes. From this perspective, there is a need for services to spread the knowledge about such changes, or the risk of such changes, and the implications of such changes.

2.4 Maintaining Authenticity

In general, any process and transformation could have side effects on digital data and corrupt its usability and integrity of the information being preserved. Therefore, authenticity requires more than just digital digests (e.g. checksum) – because these cannot by themselves guarantee that the data has not been altered, by accident or on purpose, by those in charge of the data and digests. Moreover the data may have been transformed from one form to another over time for a variety of reasons – the bit sequences and therefore the digests will change. More generally authenticity is not a yes/no issue – such as "does the digest match or not" – but rather a degree of authenticity judged on the basis of technical and non-technical evidence.

2.5 Supporting Practical Business Models for Data Preservation

Preservation of data requires resources and long term commitments; an important aspect is therefore the need for business models in order to build business cases for well identified "research assets" which can justify their continued funding. At the same time the costs of preservation must also be reduced by avoiding unnecessary duplication of effort and wasting of resources, including energy. For instance, it may be financially more viable to turn an existing storage system into a preservation archive by integrating preservation services and tools into the existing system than to create a separate preservation archive. However, no organization can guarantee its ability to fund this storage and those responsible for the data will change over time. Long-term sustainability requires more than good intentions. It requires funding, and the recognition that the costs must be shared wherever possible. It also requires one to be realistic and recognize that no one repository can guarantee its existence forever; one must be prepared to hand over the digital holdings in a chain of preservation which is only as strong as its weakest link – and the hand-over from one link to the next must be easy and flawless. This hand-over is not just transfer of the bits but also the information which is normally held tacitly in the head of the data manager or embedded in the host data management system. We envisage that suitable and efficient services and tools can help prepare repositories for the hand-over process and moreover share the results and experience with the wider preservation community.

3. THE SCIDIP-ES PROJECT

The SCIDIP-ES consortium puts together a group of partners, which covers from two different perspectives the theme of digital data preservation.

On one side is constituted by earth science data creators, curators and providers. It is constituted by three main European Space Agencies – such as ESA, DLR and CNES – plus data curators and providers belonging to a wider Earth Science community, including STFC, NERC, INGV and ISPRA.

The consortium also includes partners coming from a consolidated path of digital preservation research projects: starting from the Alliance for Permanent Access, it includes technical, commercial and academic partners involved in the last decade on digital preservation projects such as CASPAR [6], Parse.INSIGHT and SCHAMAAN, etc. These include industrial partners – ACS, Engineering, ICT, GIM, CapGemini – and partners belonging to the academic world: JUB, UTV, Forth, FTK.

The project's aims

- Upgrade CASPAR prototype components into scalable, robust e-infrastructure components to support digital preservation of all types of digital objects.
- Harmonize policies, ontologies and semantics for data preservation and future use.
- Set-up a European framework for the long term preservation of Earth Science data

SCIDIP-ES Services and Toolkits

Preservation requires, besides keeping bits, ensuring the information encoded in a digital object continues to be usable, and there is evidence that the digital object is what it is claimed to be. The SCIDIP-ES services and toolkits help this to be done. To ensure these services have a user base after the project we must ensure that the services are tuned to Earth Science repositories' and users' existing systems, showing that at least some consortium data – new as well as old – is usable where it is unfamiliar. The services must be shown to be usable by and customisable for other communities and must be implemented in a way, which allows them to be supported, by the end of the project. All of the tools and services must be designed to be customisable so that they can fit into existing (and we hope near future) systems and applications. The “core” of each of the services, which can be customised for a variety of domains and systems, must be easily maintainable and supportable after the end of the project. The toolkits will be run on various peoples’ desktops whereas the services themselves could be run by a single organisation, shared by everyone in that organisation; alternatively they could be run by a variety of organisations, sharing the services between each other or even with outside users.

Harmonization of Metadata, Semantics and Ontologies: The SCIDIP-ES project, after performing a survey on the current metadata, semantics and ontologies available for Earth Science data and on the current related initiatives, will define and validate an appropriate strategy to have harmonized metadata, semantics and ontologies able to satisfy user needs coping with the different Earth Science domains approaches. The strategy consists for example in the definition of a common ontology targeting at covering all, starting from a subset, the possible Earth Science applications domains and data categories or, more likely, at demonstrating the viability of a “semantic mediated access across domains” approach able to make the different available ontologies communicate between each others. For what concerns the metadata harmonization, we will analyse and extend the HMA approach and results to other data categories exploiting the experience of the consortium members. We will moreover harmonise the information models used for earth observation data with the ones used for insitu, airborne, balloons, etc. This activity shall address the harmonisation of the data in point via the analysis of recommended standards and best practices in the field and so propose an efficient costeffective methodology for applying such harmonisation. In particular an harmonized information model for all kinds of raster data occurring in the Earth Sciences will be developed. Examples include 1-D in situ sensor data, 2-D EO imagery, 3-D image time series (x/y/t) and exploration data (x/y/z), and 4D climate and ocean data (x/y/z/t). Based on a common raster query language such data can be integrated seamlessly across all Earth Science domains, enabling for unified cross-domain access (e.g., integrating climate data with GIS data).

ES Data Preservation Policies:

After performing a survey on the current preservation policies and guidelines available for Earth Science data, we will define, starting from the outcomes of the survey, common data preservation policies applicable to all Earth Science data categories in order to pursue harmonization of the preservation approach of the different data producers and providers to the maximum extent within and among the different data categories with the goal also to minimize costs and maximizing interoperability and synergies. The common policies will also contain the definition, to the best today understanding, of the knowledge associated to each data category to be preserved in the different data domains to satisfy today and future user needs. The definition and application of these policies will help to create a collaborative framework among Core Earth Science data user communities (e.g., land, ocean, atmosphere..) and data owners in Europe. The harmonization of rights and Intellectual property frameworks for the access to Earth Science data and associated knowledge will also be analysed and addressed in line with EC directives and International agreements such as INSPIRE and the “GEOGEOSS Data Sharing Principles” with the goal to pursue harmonization and simplification of access for users. The possibility to define and propose new data access policies for example for some subsets of Earth Science data (e.g. Earth Observation Historical data) will also be considered.

Earth Science LTDP Framework governance model and architecture

Impact analysis on the current infrastructure of the different initiative participants in the different data domains will be performed in light of the Earth Science Infrastructure principles. The architecture of a European Infrastructure, based on the upgrade and federation of existing components and on the integration of the generic services developed in the project will be defined. In addition to technical infrastructure and capabilities, the long-term management of Earth Science data requires organizational sustainability to provide continuing stewardship to address the risks to scientific data and support their use by future communities. Providing sustainable infrastructure for the preservation of scientific data requires organizational commitments, capacity, structures and plans for data stewardship that are consistent with the missions of the organizations that accept the responsibility to serve in data stewardship roles. Alternative approaches to attaining organizational sustainability for interdisciplinary human dimensions and polar data are discussed in terms of recent recommendations for organizational sustainability to foster digital preservation. To this end SCIDIPES will also define the governance and organization model of the ES infrastructure with the goal to achieve sustainability in the long term, according to the sustainability models adopted for example in the ESFRI projects, and to pursue a maximisation of the open access to data for users respecting individual provider’s data policies where necessary.

General Approach

The project approach is informed by the recently published HLEG report, which calls for an international framework for a Collaborative Data Infrastructure. One aspect of their vision was that “Researchers and practitioners from any discipline are able to find, access and process the data they need. They can be confident in their ability to use and understand data and they can evaluate the degree to which the data can be trusted”. The SCIDIP-ES team will take address of these in the following ways:

- By working closely with real users, in particular but not limited to the Earth Science domain, and building what they require, thus ensuring their adoption of the infrastructure services.
- By ensuring there is an effective governance and maintenance of the services from the start, and by not trying to impose a top-down system, the consortium will help to ensure that there is an infrastructure which is not too complex to work.
- By addressing disciplinary and cross-disciplinary strategies for metadata definition we will ensure that data can be re-used.
- By applying the subsidiarity principle – so we do not to appear to tread on researchers’ toes – and taking advantage of the growing need for researchers to use data from outside their own discipline, we will overcome lack of willingness of projects/funders/nations to take part and use the infrastructure services.

4. CONCLUSIONS

The proven generic services developed in SCIDIP-ES will be tailored to the Earth Science domain specific needs. Harmonization of rights and Intellectual property frameworks for the access to Earth Science data and associated knowledge will also be analysed and addressed in line with EC directives such as INSPIRE and the “GEO-GEOSS Data Sharing Principles”. The goal is to achieve sustainability in the long term, according to the sustainability models adopted for example in the ESFRI projects to facilitate access to data for users, while respecting data providers’ policies where necessary. As such the Initiative will pave the way for the establishment of the core of a persistent and robust Earth Science infrastructure in Europe, starting from the infrastructure of the partners involved in the SCIDIP-ES consortium, able to respond to the needs of data-intensive science applications addressing for example environmental, climate change (for very long term data analysis integrating historical data taken by historical / scattered instrumentations with recent, more sophisticated, sensors) and disaster monitoring (immediate response to unknown situations for generating specialised operation information). ESA experience in the set up of the GMES Space Component and Coordinated Data Access System (GSCDA) will be a fundamental and unique skill able to guarantee the success of the SCIDIP-ES initiative.

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QUANG TRI OLD CITADEL IN VIETNAM ON THE PATH TO SUSTAINABLE TOURISM: HISTORICAL MEMORY AS AN INSTRUMENT FOR A REQUALIFICATION PROJECT

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KEY WORDS: Sustainable Tourism, Historical Perspective, Old Citadel System, Walls Recovery, Architectural Design

ABSTRACT:

The aim of this study is searching and forming about the innovative solutions in preservation of the culture heritage and historical sites. The restoration of damaged heritage represents a fundamental theme in the architectural debate to provide answers at an international level. The history of civilisation reveals that the great cities of the past were destroyed by war. These destructive forces threaten the structural heritage of our great cities, putting the entire political and religious system in jeopardy.
The research concentrates on the case study of Quang Tri Citadel where the culture and history experienced two wars, the French and the American one.
The methodology of this study is based on the field survey, oral history, and social participation. Therefore it is appropriate to include a historical perspective in the project, assuming it unfolds on three levels within the defensive belt represents a constant and integral element of the scheme: the technical recovery of the walls, the functional transformation of the existing foundation in order to improve sociological topics, the level of architectural studies and proposals. The result of this research illustrates a new approach of the scientific debate to the cultural and historical values of the sites.

1. INTRODUCTION

The restoration of damaged heritage represents a fundamental theme in the architectural debate to provide answers at an international level. The Architectural Section of the Department of Civil and Building Engineering and Architecture of the Università Politecnica delle Marche is taking part in the debate with activities and research linking the conservation of memory and places of historical significance to research into solutions compatible with the sustainability of these locations (Figure 1).
The history of civilisation reveals that the great cities of the past were destroyed by war. These destructive forces threaten the structural heritage of our great cities, putting the entire political and religious system in jeopardy. This is the case of the Ancient citadel of Quang Tri, situated in the Province of Quang Tri in central Vietnam and founded in 1809, forever recorded in history and erased architecturally by the battle in 1972.
The Citadel system in Vietnam is an expression of the history, culture, technical and artistic heritage of the society of a specific historical period; Vietnamese society generated a very interesting urban type, documenting factors such as the orientation, topography, a primarily agrarian economy revealing similarities between the most ancient Asian traditions and elements of fortified European cities. Generally, these are attributed to the Vauban style in the case of Vietnamese cities dating back to the Nineteenth century. Chinese colonial occupation lasted over a thousand years in Vietnam. French colonialism started in the second half of the nineteenth century and lasted less than a century, leaving an important heritage of intellectual and urban development, influencing the infrastructure of major cities in Vietnam. These places serve the function of historical reappropriation just like the oxymoron between regulation and fruition provides resolutive elements in the definition of innovative strategies aimed at motivating cultural and jointly liable tourism, the impact of which consists of potentially positive impacts on socio-economic growth of the populations involved.

Figure 1: The Italian and Vietnamese scientific staff and the local authorities visting Quang Tri in June,2011

1.1 Urban, infrastructural and climate overviews about case study

Quang Tri citadel is located in the center town of Quang Tri which belong to Quang Tri province in Vietnam.
Quang Tri town is a small zone with 40 km2 and 22.760 people of population. In general, Quang Tri town is the area with underdeveloped economics, most of people work in agriculture and fishing. In addition, Quang Tri is faced with low infrastructure. The street is narrow without drainage systems, especially all the streets around citadel. Besides that, the citadel is located beside Thach Han River with 230 m distance. This is the lowest place of Quang Tri town.
Therefore, in the rainy season, the citadel and all streets flood with water. In fact, in 1983 and 1990, the highest water level was from 2 m to 2.5 m. These were the causes of the rapid degradation and road damage, and erosion impacted on the citadel. However, Quang Tri citadel is located in a good situation with the convenience of waterway, road, and railway. There are the connections inside the province by road and waterway, the connection of Quang Tri town with Cua Viet port, and other ones by the railway from North to South. On the basis of these advantages and disadvantages, the preservation and sustainable development are urgent problems.

Figure 2: 1972, Quang Tri Old Citadel after the battle

1.2 The formation and the history Quang Tri Citadel

Quang Tri citadel is a historical monuments of Vietnam which is famous for the second battle of Quang Tri began on June 28th and lasted 81 days until September 16th 1972, between Vietnam People's Army and Army of the Republic of Vietnam backed by United States of American.
The formation of Quang Tri citadel goes through many historical periods.
Firstly, Gia Long, the first king of Nguyen dynasty, built the citadel in 1809.
It was built with clay soil but it was destroyed gradually because of climate. In 1827, Minh Mang king carried on rebuilding by brick, made of the mixture of calcium hydroxide, and condensed sugarcane.
The citadel's shape is a square. The perimeter of the wall is approximately 2000 m , the area is 3 kilometer square. The wall is 6 - 7 m in thickness of the feet and 2.5 m of the top. The citadel has four main doors at North, East, South, and West with the dome form with 3.4 m of wide, the top is observatory with a curved roof.
The citadel is surrounded by a water canal system and the four corners are the four high forts. Following the history documents, inside of the citadel there are about nine buildings, Hanh Cung (is the biggest building of king office and festival organization), Tuan Vu, An Sat, *Lanh Binh, Ty Phien,* test school, military camps, flagpole. In the years from 1809 to 1945, the Nguyen dynasty took this place as the military stronghold and administrative headquarters.
From 1929 to 1972, the French built more houses, such as prison, and turned this place into a place of detention of people with opposing political views and more police courts, soldiers camps, tax authorities officers.

After the Quang Tri battle 1972, the citadel was destroyed, many parts of mortal disappeared, only the brick part remained. Some brick part were broken, as can be seen in the soil inside (Figure 2).
In addition, part of the old prison was built from brick, concrete and rock; nowadays only the rock part still remains. It was also destroyed by bombs and bullet.
Each piece of land has blood and bones of those soldiers (Figure 3), therefore, the citadel can be considered as a common grave which buried about 10 thousand people, mostly in their twenties.

Figure 3: Picture from Quang Tri battle, 1972

2. THE RE-BIRTH OF QUANG TRI OLD CITADEL

The walls are the cardinal element underlying a variety of themes representing the meaning expressed by Quang Tri Old Citadel.
The walls surround an extensive area where the layout of two orthogonal axes oriented on the basis of the cardinal points. The point where they meet is currently marked by an altar devoted to the cult of ancestors. Four gates correspond to the extremities of the two axes. The urban shape is square "*in line with ancient Chinese theories which imagined the earth to be quadrangular*" (M. Morini, " Atlante dell'urbanistica").
The orthogonal scheme does not evolve rigidly except in its essential lines and it is characterised by large open spaces.
The defensive walls record the overlay of historical memory throughout different periods (Figure 4). These were ruined by wars. Shattered bricks provide clear evidence of the violation of the sanctity of the walls and the human events that unfolded in this place.
The devastated walls were covered by thick vegetation like a citadel taken by force (Figure 5).
It is appropriate to include a historical perspective in the project, assuming it unfolds on three levels within which the defensive belt represents a constant and integral element of the scheme: the technical recovery of the walls, the functional transformation of the existing foundation in order to improve sociological topics, the level of architectural studies and proposals.

Figure 4: East gate front of Quang Tri citadel

2.1 The level of technique and social participation: the recovery of the walls

The planned restoration of the historical walls requires existing parts to be restored in compliance with best workmanship standards and cutting edge building techniques in accordance with the original construction.
The restoration plan will respect the original structure and limit the extent of substitution and removal, instead of completing the parts that crumbled and were destroyed.
The required operations will take place in the following phases:
- historical and documentary analysis, on the basis of which potential construction scenarios will be proposed to determine the heterogeneity of materials and techniques used;
- direct analysis of the structure;
- enquiries and proof, to determine the mechanical and chemical-physical characteristics of the materials of the walls;
- identification of contemporary materials compatible with existing materials to restore the structure, safeguarding its aesthetic and historical identity.

A training course and a laboratory will be established for the above operations, with the presence of young Vietnamese technicians which will be guided by expert teachers.
In addition to the specific skills of technicians, the process for the recovery of the walls could be realized through the work of volunteers; these volunteers must be chosen between the inhabitants of the Province of Quang Tri, but they also could be intellectuals which are interested in the conservation of this heritage.

Figure 5: Quang Tri, actual views of the wall

2.2 The level of sociology and communication: museumification on the path to sustainable tourism

A historical site in general and Quang Tri citadel in particular includes many values such as cultural, historical, and architectural values (Figure 6).
Cultural value is the patriotism; it affects the visitor with the significance of patriotism education of its country. The historical values mark a flourishing period of the Nguyen Dynasty, the evidence of cruel war and the heroic struggle of Vietnamese.
Therefore keeping this value is the preservation and proposal solutions for the future.
The building site at Quang Tri has substantial untapped potential; this model should be included in the more traditional tourist itineraries as a strategic point in planning innovative tourism along the major itineraries of the South Central coast of Vietnam to enhance local attractions.

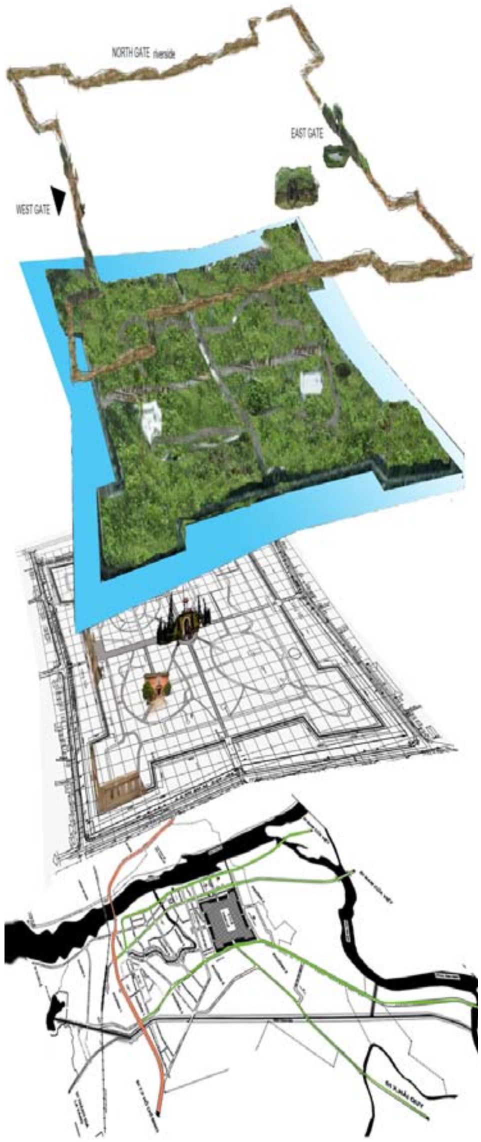

Figure 6: The categories of Quang Tri Complex: connections, existing buildings, green spaces and the walls

These attractions represent instruments for the international promotion of the territory of Central Vietnam, where there are current initiatives such as "National Tourism Year 2012" promoted by Thua Thien Hue Province, involving the important city of Hue, which was the last imperial capital of Nguyen dynasty (1802-1945) and is one of the UNESCO world Heritage sites, and where the model of the fortified citadel is put forward in the Ancient Citadel of Hue. The activities of this year are an occasion to advertise the potential of tourist attractions in Central Vietnam.

It will be the result of a participatory process involving population, historians, and social scientist based on the historical awareness acquired. It will also represent a new idea of jointly liable social tourism.

Furthermore the museum is not only the place to put items on display, but also a digital world to promote both the history of Quang Tri and the monumental sites in the Asian countries.

In addition, such a digital museum will use Information Technologies for communication between past and present.

In fact, advanced technologies will be applied through the use of digital applications that will play a fundamental role as means of communication: virtual images will represent to the visitors the architectural analysis of the system of Old Vietnamese Citadels, the memories of the war in Quang Tri, the researches related to the identity of the Asian territories and 3D documentation of archaeological sites.

Therefore the museum will promote Virtual Exhibitions of multimedia data, digital documentation and real-time applications about architectural and historical culture.

The aim of the use of innovative technologies is to involve the visitor to improve the dialogue between the historical knowledge and its contemporary comprehension.

2.3 The level of architectural design: formal and compositional research

The third level concerns the architectural analysis and the conception of the project.

As mentioned before, the other value of the historical site is architecture, because it marks the morphological features of a period; specifically, the citadel has a role in recognizing the form of military wall in the Vietnam War.

Therefore at a compositional level, the walls should not be disturbed by a plethora of architectural objects and the area within the walls should be almost completely free.

The proposal of design concept is very important in this type of construction. In fact, a moderate work must be in harmony with the surroundings, but also leave the impression to the visitors providing emotions to the viewers with the sustainable connection.

Therefore, the project process works through accurate 3D architectural representations of the Citadel of Quang Tri, in order to study the impact of the project on its environment. The three-dimensional visualization is used as a valid instrument both to design the museum system and to represent the proper hypothesis of architectural interventions.

The museum, which will use applied technologies, could be a building located underground as a part of overall. It will be an integral part of the surrounding landscape, as the factors that currently exist and the sustainable development of the project depends on this impaction.

Figure 7: Analysis of the impact of the project on its context

Figure 8: Studies for the compositional research for an underground museum

Some hypothesis about the design idea of the museum's apparatus are studied through 3D perspectives to achieve the highest concord with its context.

The museum could be immersed in a green space simulating the memorial space. It is created from the same layer with the surrounding objects with the entrance on lower level from the plan ground (Figure 7).

The second idea (Figure 8) highlights the idea of harmony.

The museum is placed underground dividing the grass in two layers having different altitude: the highest is at the same level of the plan ground and the lowest has the entrance giving the feeling of unity between the two objects.

Finally the free area inside the wall represent a solution which is guided from the memory of the past.

3. CONCLUSIONS

Old Citadels built by South-East Asian civilisations have a specific historical relevance and their own features.

They provide a basis for scientific thought on themes that safeguard sustainability and the relationship with neighbouring regions.

The path to sustainable tourism combines cultural and environmental factors and is functional to the development of social-cultural tourism, in search of real evidence of different reference contexts - to produce benefits on socio-cultural areas of interest.

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ROUTE OF THE WORLD HERITAGE MONASTERIES IN PORTUGAL AND A DIGITAL TOURISTIC PLATFORM

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KEYWORDS: Culture, Tourism, ICT, Sustainability, Economy, World Heritage Monasteries, Portugal, digital contents, digital libraries, Europeana, social networks, 3D, virtual reality, augmented virtual reality.

ABSTRACT

We present the ongoing project *Route of the World Heritage Monasteries in Portugal* and emphasize the planned Digital Touristic Platform. It's been created as a partnership between local authorities where those monasteries are located and with higher education institutions and the National Management Institute of Heritage. It is been financed by European funds over 14,4M . We describe the strategic plan, the key actions and the model of governance. The role of the Information and Communication Technologies (ICT) on growth and on employment related to cultural heritage and tourism is then approached referring to e-business and digital platforms particularly. We present the results and some new start-up projects as a result of the created synergies. The importance of Heritage Economics with the use of ICT as well as the lessons learned so far are analyzed.

Keywords: Culture, Tourism, ICT, Sustainability, World Heritage Monasteries, Portugal, digital contents, digital libraries, Europeana, 3D

1 PROJECT DESCRIPTION

The design of the Route of the World Heritage Portuguese Monasteries is the result of a network established between the municipalities of Lisbon, Batalha, Alcobaça and Tomar, and the Polytechnics Institutes of Tomar and Leiria, and the Portuguese Institute for Heritage Management. The route is a world set of unique Cultural Heritage (CH): The Templar Castle and Convent of Christ in Tomar, the Monasteries of Alcobaça, Batalha and Jerónimos in Lisbon. The total route distance is about 280 km between these cities and it takes about 2.5 hour's drive by car. The relative positions are shown in Fig. 1. In that map, the Shrine of Fátima is also identified, between Tomar and Batalha.

This set is a thematic and identity anchor of their towns internationally. It reflects the crossroads of major international currents of history, culture, ideas, and spirituality and Intangible Heritage - the Cistercian Order and the Order of the Templars and the Order of Christ and the Portuguese Discoveries.

The creation of the route network aims to increase the scale which encourages the development through the principle of sharing and integration: fewer resources are used, the results are more effective, durable and supportive, so that it creates partnerships with public and private citizens. The use of Information and Communication Technologies (ICT) facilitates and enhances the interactivity between citizens and touristic and cultural products - shortens the distance between consumer and product providers.

Fig. 1 - Route of World Heritage Monasteries (Portugal)

The public offering of new services, new applications and new skills associated with management practices and cultural tourism resources resulting from cooperating partners are factors of competitiveness at different levels: research, education, cultural production and cultural promotion and production of digital content.

1.1 Financing and Strategic Plan

The project was approved in June 2009, signed the contract in September 2010 and should be completed by 7 September 2014. It was submitted as "Instrument of Cities Policy - Urban Networks for Competitiveness and Innovation". The total investment approved is 14,4M and 10,7M reimbursed by European funds.

The Strategic Plan (Plano Estratégico da Rede de Mosteiros Portugueses Património da Humanidade, 2010) is based on *i)* cooperation between cities in potential and vocation issues, reinforcing the differentiation factors, attractiveness, competitiveness and internationalization dynamics *ii)* consolidation of collective dynamics of urban development focused on innovation and knowledge; promotion of attraction and establishment of innovative activities and qualifying human resources and creative professionals *iii)* international projection image, resources and activities. It goes through *i)* create a brand for a cultural tourist product based on *qualitative* factors (World Heritage) and *quantitative* factors (visiting 4 monasteries located at most an hour away by car between them) *ii)* assume a world heritage site as a competitive factor for the locals and global inhabitants, encouraging visitors to learn more about the territory and extend their stay by transforming the resources of urban centers in effective tourism products *iii)* value added and qualification of the city center providing qualified touristic services, keep boosting the touring and cultural landscape, with an improved visitor experience and qualification of hospitality *iv)* a new paradigm in knowledge sharing between cities, with cooperative efforts between agencies, multiple levels and spheres of activity around a common purpose: the enhancement of CH and increase the competitiveness, with Lisbon as an example for the quantum leap is to achieve competitiveness in the touristic cities; *v)* competitiveness of the route for enhancing competitiveness and territorial cohesion of the arc route also using the proximity to a major destination for religious tourism in the world, the Shrine of Fátima, *vi)* Promote partnerships for innovation through the involvement of a multiplicity of network partners: local authorities, institutions of the technological system, scientific and training, private entities and associations *vii)* qualify human resources and strengthen social skills and cultural agents of the cultural sector to encourage community building through creative cultural productions and promoting actions in the roaming network.

1.2 Key Actions and Governance

The key actions are *Identity* (8.2M , 38%) that emphasize the unique and individual traits of the Portuguese: its universality, history and culture; A*ttractiveness* (2,9M , 35%) lies in the historic resources, cultural environment and socio-cultural ambience as a unique experience; *Receptivity* (0.5M , 8%) is a competitive advantage but it presents difficulties to overcome such as poor signaling, inadequate hours of operation and insufficient in multilingual information; *Interactivity* (0.2M , 1%) using the internet through various channels is essential in tourism, culture and business for new opportunities as the relations between consumers and products are changing; *Visibility* (1.9M , 13%) with media and appropriate marketing; *Continuity* (0.7M , 5%) in the perspective of the management of this project after its implementation.

For the *governance* the principle of partnership cooperation was adopted, looking at the medium to long term by ensuring the participation of all partners, and flexibility in procedures. Supports up into three separate structures: a steering unit with all the institutions involved, a technical support structure and a board of supervision and monitoring. Was also set up a private association, the MPH (Monasteries World Heritage) to manage funding of joint projects from the four municipalities.

2 ICT, GROWTH, EMPLOYMENT AND CULTURAL HERITAGE ECONOMICS

The first initiative in the Europe2020' strategy was to create the Digital Agenda 2020 - make every European digital. ICT currently represents 5% of the European GDP and contributes to about 50% for competitiveness: is a factor for growth and employment. Digital libraries and the production of digital content and action plans for cultural heritage are promoted by the Digital Agenda.

The CH seen in a perspective of economic and sustainable development is based on a set of products that should result in a new value chain (Reis & DeMarco, 2009). Design a prospective integrated, coherent and sustainable for qualifying urban, social and environmental dynamics (Hugues, Hirczak, & Senil, 2006) are the engine for promoting cultural tourism. In this context, the use of ICT is a crucial factor while preserving (digitizing), disseminating (Internet, Europeana, social networks, virtual reality (Guidi, Frisher, Lucenti, Donno, & Russo, 2008) and augmented virtual reality, learning and eLearning (Forte, Pescarin, & Pujol Tost, 2006) and inclusion (Mendes, All Inclusive Digital Town and its Villages, 2000). It also allows to achieve significant economies of scale and greater brand visibility, as well as a qualified and differentiated interpretation in visitation through access to a multidisciplinary digital content and wide use. Also, there are a set of recommendations for the cultural web sites (Commission, CULTUREMAP Mapping and evaluating existing platforms (websites) within the cultural sector aimed at stimulating debate and cross-border exchange of matters concerning European culture, 2010) which are spreading all over the world.

ICT can be very helpful in the study and monitoring the definition of criteria of authenticity and preservation of the cultural value integrity, respecting the cultural and social context in which they enroll. The human memory is an advantage for the development and sustainability to structure a solid foundation for the revival and revitalization of the cultural value. This solid foundation helps to reduce wear and loss of integrity, when demand is excessive (e.g. Pompeii and Jerónimos Monastery (Goral, 2010)). The thematic networks enable flows to redistribute and rebalance the phenomenon of attraction, and the elements with higher uptake capacity contribute to the sustainability of the least known or apparently less appealing. The creation of networks of exchange and sharing CH information through a digital knowledge platform are critical for citizens, enterprises, government and researchers. The management of the shared heritage is central to the different interests and values favoring the integration of different areas of knowledge and creating a new chain value. A common strategy, with multidisciplinary teams, with new responsibilities for management and exploitation of the region should be assumed as a foundation for economic and social sustainability and not as a consequence. The value of these cultural heritage, whether local or global in space (Ortiz, 2007) and, the challenge of employment and qualified training introduces into debate not only the potential of ICT innovation and creativity but also the emergence of a new discipline: Economics of Heritage as an essential pillar of the territory and political communities (Bispo, 2011). The development is inseparable from the strengthening of tourist attractiveness, based on creativity and creation of products such as touring cultural routes (e.g. route of Templar's, route of Cistercians (Martins, Cistercian Architectural Heritage as Cultural Landmarks, 2010) or the route of Jewish Quarters). The Heritage is the people. It is not a closed matter subjected to management with strict rules: the active social life of citizens, the transversal of areas they pass through, the multicultural realities and multiple opportunities are continuously modified. The values and meanings associated to CH are a socio-cultural subject having new criteria for facing the changing concept of Space-Time. The transformation of economic and social dynamics determine, inevitably, the change of the principles of integrity, authenticity (Alho, Morais, Mendes, & Galvão, 2010), preservation, enhancement and safeguard of CH.

2.1 Emergent Tourism Tendencies and eBusiness

New trends emerge in the tourism and culture business: auto personalization (the consumer draws your product); ebusiness (between consumers, businesses and government) (Commission, ICT and eBusiness in the Tourism Industry, ICT adoption and eBusiness activity in 2006, 2006); thematic segmentation of markets (clusters of excellence); changes in the value chain (the consumer is closer to product); emarketing (instant, customized); interaction (multiple channels of communication via the Internet where the consumer navigates freely).

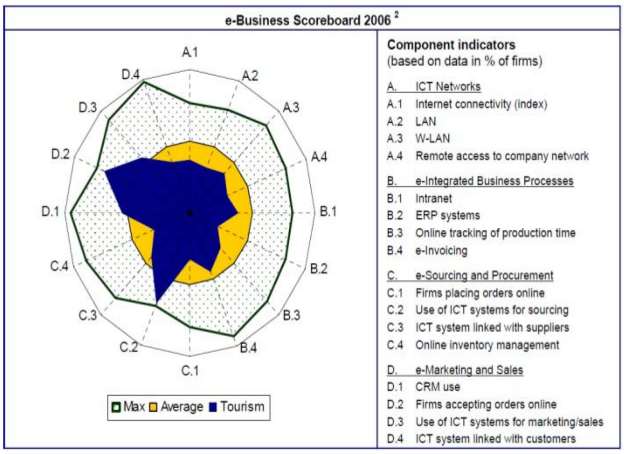

Fig. 2 – eBusiness in Tourism

The ebusiness in tourism is above average in ICT as a resource, management of customers, accept orders online, marketing and sales. On the other hand, is on average in use of Intranet, electronic invoicing and consumer liaison (

Fig. 2).

The interaction is increasingly important for citizens, businesses and government: the provision of new services and new applications allows tourists to negotiate the best conditions for their journey and make visitation as a unique experience in terms of interpretation and enjoyment. ICT enables a noninvasive intervention, preservation and integration into the fruition of CH.

2.2 Touristic Digital Platform

An architecture for the digital platform is presented in Fig.3 (Tian, Junping, Zengqi, & Yingmin, 2010). This is the base model adopted so far for the route of the monasteries (Mendes, Projeto Plataforma Digital - Análise Síntese da arquitetura, serviços e funcionalidades; Rede de Mosteiros Portugueses Património da Humanidade, 2010). As it can be seen we have some access channels (tv, internet terminals), some touristic enterprises and authorities, some layers (presentation, access, service management, business and data resources), some data resources (basic information, knowledge base, media library) and some application services (route planning, public services, multimedia).

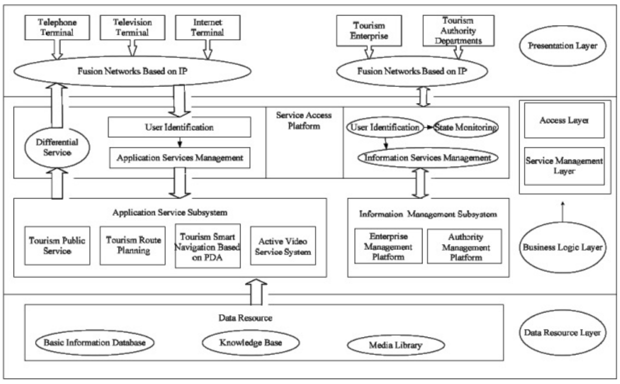

Fig.3 – Digital Platform Model

3 RESULTS

The planned investment was 14.4M and it has been defined 12.3M so far. Until December 31, 2011, had only been approved 4.5M and 1.5M executed. The financial implementation of the program is 31% of schedule. Only 42% of the funds applied for were approved, indicating a low rate of approval by the national structure of management (Relatório de Execução Anual 2011, 2012).

To build infrastructure for the qualification of public spaces in the vicinity of monuments (access roads, parking spaces, reception) are ongoing. Some actions have been developed and animated series programmed (concerts, theater history, colloquia). There are ongoing contests for roadmaps visitation and interpretation and to implement the digital platform. It´s already been done some promotional traditional marketing.

Table 1. Ratio Approved / Programmed (from achievements report) M

Key Action	Action	Programmed	Submited	Aproved	Aprov/Progr
KA1 Identity (38%)	A1 Qualifying public spaces	5,553	5,081	1,871	34,3%
	A2 Events	2,640	2,419	0,729	27,6%
KA2 Actractivity (35%)	A3 Qualifying cultural and museological equipments	1,286	0,962	0,962	74,8%
	A4 Routes of visiting and interpreting	1,075	0,932	0	0%
	A5 Reception to visitors	0,542	0,286	0,256	47,2%
KA3 Receptivity (8%)	A6 Qualifying touristic services	0,548	0,548	0,205	37,4%
KA4 Interactivity (1%)	A7 Digital Touristic Platform	0,200	0,199	0	0%
KA5 Visibility (13%)	A8 Marketing, promotion and communication	1,909	1,470	0,481	25,1%
KA6 Continuity (5%)	A9 Cooperation	0,684	0,426	0	0%
TOTAL		14,437	12,323	4,504	31,1%

3.1 Developed Work

As a Professor, on behalf of the Institute Polytechnic of Tomar (IPT), we are part of the team steering the project. We worked in the design and application for funding the project, in the planning of their implementation, and monitoring of development and implementation.

As Director of the ICT unit of the IPT we lead the team who has participated in the work involving the use of ICT in CH. Within this framework we developed studies and advice to support procurement of enterprises for execution of subprojects, e.g. touristic digital platform and roadmaps for urban visitation.

As for touristic digital platform we adapted to the reality of world's heritage monasteries in Portugal, the already mentioned above: European recommendations for cultural sites including knowledge data bases, elearning, digital libraries and digital contents; the platform architecture proposed by (Tian, Junping, Zengqi, & Yingmin, 2010) connecting citizens, businesses and government and; the use of new e-business models with features such as happens in customer relationship management, enterprise resource planning and business intelligent applications. This study resulted in a document that was approved by the steering committee towards the project to underpin the specification for the development of touristic digital platform.

As for urban visitation itineraries we promote meetings between the technical teams of the IPT and the Institute Polytechnic of Leiria (IPL), specialists in ICT, Tourism and Culture. These meeting were to define the forms of heritage resources and urban routes visitation. Also, to define what resources in ICT equipment and applications to use on those urban visitation routes. There were defined points of visitation in urban circuits and which data to be collected (text, sound, image and video) from each of those points of visitation. The IPL will develop circuits visitation and data collection in the cities of Alcobaça and Batalha and IPT will develop circuits and data collection in the city of Tomar.

3.2 Work Planned

The specifications for the call to implement the touristic digital platform is nearing completion for subsequent approval at a meeting of project steering and later called candidates for execution and implementation of an estimated 0.2 million sub project.

The data collection for urban circuits visitation will begin in November 2012 with an estimated completion circuits for urban visitation late 2013.

Portugal is going through a difficult time economically and are underway by the current government reassessment of all projects funded by Europe. Awaited indications on whether there is any consequence for the remaining funds not yet implemented.

Resulting from synergy, we are organizing a Conference on Jewish Heritage (1st International Conference on Jewish Heritage, science, culture, knowledge) and a Conference on the Philanthropic Heritage (I Conferência Filantropia e Arquitectura 2012 - Periodo 1880-1920. Call for papers).

3.3 Related new projects from new synergies

There are some start-up projects resulting from synergies created: the *Route of Cistercians Monasteries*, the *Route of Jewish Quarters*, *Thousand Years of Wisdom* and *The Route of Philanthropic Architecture* (Galvão & Mendes, Philantrophy and Archictecture, 2011).

In the *Cistercian Route* is intended to create a database with the cataloging of this Order assets (Martins, Património Arquitectónico Cisterciense: um contínuo testemunho, 2011) available through the Internet and allowing citizens and researchers to analyze this CH and its evolution over the centuries. The *Route of Jewish Quarters* intends to show a Jewish presence in Portugal integrating this knowledge with the network of Jewish Quarters in Spain thus covering the territory of Sepharad. In particular, the Synagogue of Tomar (Schwarz, 1939) is the oldest (Sec XV) preserved in its architectural structure in Portugal, Spain an even in the world. The initiative *Thousand Years of Wisdom*, aims to apply ICT to the Convent of Christ by creating new products, services and applications (Mendes, Mil Anos de Sabedoria, da idade média ao século XXI, Tecnologias de Informação e Comunicação no Convento de Cristo, 2010). Some of these digital contents are in a 3D format (Mil Anos de Sabedoria, TIC no Convento de Cristo, 2010) revealing the importance of the virtual reality (Guidi, Frisher, Lucenti, Donno, & Russo, 2008) and augmented virtual reality. The *Route of Philanthropic Architecture* aims to understand a restricted core under the Heritage contemporary social point of view, in its genesis, function, performance and impact. All produced digital contents (text, sound, photographs, video and 3D) are taking into account to make them available to the Europeana by including Dublin core standard metadata. Digital Libraries produced (Mendes, et al., 2009) from these projects will improve services, as well as the quantity and quality of digital contents, and provide access to cultural assets that were previously scattered or not scanned. As a result, a considerable part of our European collective memory will be available online for study, research, creativity, learning, leisure, tourism, culture and business promoting the heritage economics.

4 CONCLUSIONS

This project's strategy is still up to date in view of exploiting new add value created from the world CH (Prud'homme, 2008) new products, services and applications, such as routes, digital contents, e-business and sharing management cultural and touristic resources. It is important to ensure that the strategy is in line with new national policies (Ferreira, 2011) once the Portuguese Government has changed. It is in time to implement the digital knowledge platform for sharing information and start to provide new services and applications. Strengthen partnerships between institutions involved in the project, in particular taking advantage of the vast knowledge of Lisbon, is fundamental to the assertion of the network. Despite the criteria of funding eligibility does not allow the inclusion of private sector (e.g. hotels, restaurants) it is important to foster partnerships so that each one contributes with its resources and skills. There is therefore a total divorce between the project and the private sector that has to be filled to increase the impact on tourism, cultural services and products. The Shrine of Fátima (5,8M visitors per year) is important for the project despite not being directly integrated in the network shares.

In operational terms it is recommended to increase the efficiency of the national approval funds even knowing the complexity of documentation and procedures to justify the costs and the diversity of types of projects submitted. Of fundamental importance is the installation and ownership of the board of supervising and monitoring - there is a lack of monitoring the project development.

It is agreed that financial and operational reprogramming is a critical factor to increase the overall effectiveness and make adjustments that aim to continue the strategy in the medium to long term 2014-2020. The competitive advantages in building partnerships, networks and sub networks or other thematic structures is a way to defend the heritage and territory, providing sustainability and increasing the competitiveness of communities and their local business (Galvão, Redes, rotas e parcerias estruturantes - o caso da Rota dos Mosteiros Portugueses Património da Humanidade, 2009). Also, it reduces inequalities and creates new *spaces* and *opportunities*.

An important result of the information society revolution, using ICT, is that of make it possible scaling a new ubiquitous space-time relation: anywhere, anytime. Today, although we are global citizens, we are even more local citizens. Our emotional feeling go increasingly to transnational (Canclini, 1994) issues of symbolic values (e.g. Judaism, Templar's, Cistercians). These new *communities* use ICT to interact in a more personal, experiential and emotional way. Social networks play a key role in this context: they are the tool of the 21th century for numerous fields of application and socialization as the interdisciplinary scientific and technical applicability. At this stage of transition between old and new CH conservation policy framework for an effective participation and enjoyment of the citizens who changed the shape of the demand and supply, forcing a reset communication strategies on e-business. The citizens use the Internet to build their product, build their visitation schedule, establishing from the place of their origin to an interactive relationship with the territory of destination and tourist services deployed there. This accessibility is a key factor at the moment of decisive choice, being one of the key trends emerging tourist consumption. Also the use of ICT during the visitation is critical to provide a unique experience. Develop digital platforms where citizens, businesses and government may share information and knowledge is an essential foundation for economic heritage.

In summary there is a need for greater coordination among agencies, greater participation of the business, higher activity and leadership of the national governance, increase efficiency in the coordination between the agencies involved and the effect of monitoring actions. The role of ICT is fundamental to the CH in its closure to citizens and encouraging networks between public bodies, businesses and citizens.

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PROTECTION OF CULTURAL HERITAGE OBJECTS WITH MULTIFUNCTIONAL ADVANCED MATERIALS

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KEY WORDS: Protection of cultural heritage, Atmospheric pollutants, Multifunctional advanced materials, HEROMAT, Dornava manor, Ba Fortress

ABSTRACT:

The FP7 funded project HEROMAT started in November 2011 and will last for 48 months. The aim of the project is to develop innovative and environmental friendly materials that have chemical and mechanical properties tailored with respect to the protection of immovable cultural heritage assets. Through knowledge exchange among members of the international team of experts, the multidisciplinary research will offer new solutions for protection and consolidation of cultural heritage objects by the development of innovative protective materials: self-cleaning coatings, anti-microbial coatings and consolidants with or without hydrophobic properties, which will be effective for different categories of cultural heritage objects. This project aims to contribute to an efficient and long-lasting solution for the prevention of degradation, keeping the authenticity, functionality and the aesthetic appearance of the cultural assets and remaining their socio-economic benefits. The Pan-European project team coming from Serbia, Slovenia, Italy, UK and Russia, cross-links the experts and focusses their work on the restoration and consolidation of two selected historical objects, one located in an urban (Ba Fortress, Serbia) and the other in a rural (Manor in Dornava, Slovenia) environment, both having continental climate. The targeted surfaces are inorganic mineral substrates of cultural heritage objects: stone, brick, mortar, render and color finishing layers.

1. INTRODUCTION

The cultural heritage of immovable monuments has a powerful impact on regional society and considering the wider European region, with its complex culture diversity, represents a powerful tool for the integration process from a sociological, political and anthropological point of view. Culture and works of arts are easily understandable and consequently represent the most appealing way of establishing new links among nations. In addition, cultural heritage influences the economy by establishing business opportunities with the perspective for new work places.

Because of the recognized responsibility by relevant stakeholders and the respect for the cultural heritage monuments, significant efforts have been provided to the protection against atmospheric pollutants. The long-term conservation and restoration of the European cultural heritage is considered as a shared commitment of European societies, particularly in the context of environmental protection and sustainable living. At the same time, protection of cultural heritage is a challenging task put in front of researchers and practitioners, not only due to sociological and political reasons, but also by reason of the European economy progress and the quality of life (European Conference Declaration on Sustaining Cultural Heritage Research, 2004).

In the conservation of cultural heritage buildings, scientists deal with the degradation of unique building materials, resulting from a delicate balance of aging, unpredicted events, environmental conditions, and sometimes incorrect previous restoration treatments. Together with the climate change effects cultural heritage assets are exposed to multiple risks that can lead to irreversible damage or complete destruction. Unfortunately, there are no unique solutions for the protection of cultural heritage objects and therefore there is a great need to develop a scientific approach which will combine careful planning of ordinary and extraordinary maintenance works with the selection of proper materials ensuring overall durability and sustainable development. In order to moderate the aggressive effects of the polluted atmosphere or other decay mechanisms, protection procedures must include replacement of specific sections as well as application of new compatible materials (Price, 1996).

The project HEROMAT which started in November 2011 and lasts for 48 months aspires to develop environmental friendly materials with added value functions for restoration and conservation of immovable heritage that will be evaluated in real conditions on site of specific objects: Ba Fortress (Serbia) and Manor in Dornava (Slovenia). The overall goal of the project is the improvement of the physical state as well as the resistance to degradation of the materials of monuments sustaining the functionality and the aesthetic appearance through a long period of time.

2. PROJECT CONSORTIUM

Considering the previously existing professional contacts and long-term cooperation in scientific fields linked to project research work (Hadnadjev, 2010; Sever kapin, 2008; Hadnadjev, 2008) the international multidisciplinary team of experts engaged in the project jointly contributes to solving the concerns and problems present in the protection of immovable cultural heritage through concrete work on two selected historical sites.

Project Consortium involves universities and research institutes, public organizations for protection of cultural heritage and industrial partners:

Universities, scientific and research institutes:

TFUNS - Faculty of Technology, Serbia, Project Coordinator
ZAG - Slovenian National Building and Civil Engineering Institute, Slovenia
CNR-ISTM - Institute of Molecular Science and Technologies, Italy
UWS - University of the West of Scotland, United Kingdom
NArFU - Northern (Arctic) Federal University, Russian Federation
PZZSK - Provincial Institute for Protection of Cultural Monuments, Serbia
ZVKDS/IPCHS - Institute for the Protection of Cultural Heritage of Slovenia, Slovenia

Small and medium enterprises (SMEs):

GP HGP – Construction company HGP, Serbia
SANING - Saning International Ltd, Slovenia
EURA - Eura Conservation Ltd, United Kingdom

3. PROJECT STRUCTURE

The project is organized in ten work packages out of which seven directly involve research and technological development work, while others are management, coordination and dissemination of the project outcomes. Experienced researchers and/or experts in applied research and management are the leaders with full autonomy and responsibility for the work plan, the timelines (i.e. the milestones and deliverables) and for the scientific value of the output. The evaluation of efficiency of the new composites will be carried out first on models by means of micro-destructive laboratory analytical techniques and secondly on real cases (Manor in Dornava and Ba Fortress, Figures 1 and 2) through non-invasive portable equipments (Miliani, 2010; Romani, 2010).

4. THE SELECTED CULTURAL HERITAGE ASSETS

Dornava Manor house complex with accompanying park grounds is one of the most important monuments of the late Baroque period in Slovenia.

In the past years the manor has been studied thoroughly. The investigation was based on the research of archival sources and scientific research and gave a comprehensive image about the architectural history of the manor. The first building, which is known only after engraving of Georg Matthäus Vischer, was simple and completely rebuilt around year 1700 on behalf of Count Franz Anthony Sauer by an unknown architect. Under patronage of Count Joseph Thaddeus von Attems-Heiligenkreuz the building was reconstructed in the second half of the 18th century, according to the plans of an Austrian architect, Josef Hueber (Vienna, 1715 – Graz, 1787). Although the building of 1700 remained intact, some parts were considerably expanded and decorated in the late Baroque style.

After an ambitious 18th century renovation, the mansion underwent some construction works, which over time severely damaged the building.

Figure 1: Manor in Dornava, Slovenia

Because of long exposure to strong degradation and inappropriate restoration actions the stone elements of the exterior - statues and ornaments of the garden, fences and main building - show only a faint picture of the past. After several decades of accelerated degradation the overall revitalization of the manor is inevitable.

Ba Fortress, Serbia (currently on UNESCO Tentative list) is the oldest medieval fortress in Vojvodina, the northern province of Serbia, built from 1338 to 1342.

The fortress was completely surrounded by water having a pentagonal base with towers at each angle and the tallest central tower (donjon or defender tower) inside the walls of the fortress. This stronghold of the Austro-Hungarian and Ottoman empires has been in ruins for centuries due to physical, chemical and biological degradation processes. Since the salvaged parts of the Ba fortress illustrate coexistence, mutual understanding and cooperation of people with various religion and cultural identities living there for centuries, urgent action for degradation suppression or elimination is necessary.

Figure 2: Ba Fortress, Serbia

5. MATERIALS AND METHODS

The project research involves the chain of activities from the synthesis, establishment of the methodology for characterization and testing of novel protective materials through their pilot production and, finally, to in situ application and monitoring, giving also their life cycle assessment.

5.1 Materials

The output of the project is a set of novel materials applicable for the protection of different inorganic mineral substrates (stone, brick, mortar, render and color finishing layers) providing multiple added functions: consolidation, self-cleaning and anti-microbial effect.

The protective coatings would be obtained by the application of suspensions modified by the newly developed inorganic-inorganic nanocomposites associated with photocatalytic materials, on different substrates and content ratio. The use of these materials based on anionic clays (layered double hydroxides, LDH) associated with photocatalytic semiconductors, such as TiO_2, will contribute to the overall better properties of the developed coatings on the mineral substrates. These protective coatings will be developed and investigated by the international team of experts from different fields of interest tailoring their textural and morphological characteristics and enhancing their compatibility.

Different formulations of the composites will be investigated in order to define the appropriate ratios that would regulate the water permeability, the drying process improving mechanical properties and durability of protective coatings.

The evaluation procedure of these protective layers would consist of characterization of composite materials (substrate and protective layers-model samples) and in-situ monitoring (non-invasive and micro-destructive characterization) of applied materials on immovable Cultural Heritage objects.

5.2 Methods/knowledge

Methods/knowledge which will be developed or established for the successful execution of the project, involve:

Study of coating interactions with different mineral substrates (brick, stone, mortar, render, color finishing layers) will form the basis for the design and production of novel advanced materials; and
Study of material degradation processes for cultural heritage objects in order to find the most effective solution for protection (bio-degradation and bio-receptivity, degradation due to frost action, thermal-hydric cycling, alkali-silica reactivity, sulphate corrosion etc.):

- Study of suitable methods and techniques for monitoring and assessment of efficiency of the developed materials in laboratory and on site in real time scale
- Development of the application techniques and study of the effect of the application technique on the performance of the developed materials
- Study of durability of applied materials (short and long-term effects of protective, and consolidative materials on mineral historical substrates)
- Establishment/adjustment/development of methods for characterization of functional and other important properties of unprotected and protected targeted historical materials
- Life cycle thinking in the assessment of environmental friendly advanced protective materials (assessment of environmental impact of developed materials).

5.3 Progress

The project is in the middle of the first year putting the emphasis on the sampling procedure of the material from the two selected historical sites (Manor in Dornava and Ba Fortress) that will represent the basic information for further formulation and preparation of model substrates, as well as the basic information for in situ application of newly developed materials. The prepared model substrates will be subjected to simulation of degradation and subsequently characterized. It will therefore represent a suitable material base for testing the newly developed materials prior to their application onto the selected historical objects.

The sampling at the two sites was focused on the stone elements and the facade surface with the render and color finishing layers. Seven areas were selected in the case of Manor in Dornava, while forth areas were chosen from the Ba Fortress, according to the composition and expected degradation. The materials will be analyzed by non-invasive laboratory examination (XRF, fiber FTIR, raman, NMR-mouse) in addition to invasive characterization (petrography, SEM/EDS, -tomography, contact angle measurements, biological characterization and -hardness) (Hughes, 2003; Zhu, 2007). The value of the stone statues is taken into consideration; hence only non-invasive measurements will be performed.

6. CONCLUSIONS

The FP7 funded project HEROMAT generates know-how closely linked with main research goals set at the beginning of the project and offers collaborative experience in interdisciplinary team surroundings, with versatile subsequent dissemination activities.

The special importance was given to SMEs active involvement in all project stages, providing them with valuable insight in both new research methodologies and large-scale production lines. Partner SMEs are recognized as potential important party in the processes of production of active components on the small scale, in addition to consulting and market investigations.

The approach of the HEROMAT project ensures through consortium structure it will overcome the traditional barrier in the commercializing of the research results. At the same time, it will enhance the feedback from industry to the research institutions, essential for a lasting cooperation and widely applicable results. Moreover, the consortium encompasses both experienced and young scientists, offering the synergy of gained knowledge and fresh ideas, crucial for overall success of the project.

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Research area: ENV-NMP.2011.3.2.1-1 Development of advanced compatible materials and techniques and their application for the protection, conservation and restoration of cultural heritage assets
Type of funding scheme: SME targeted Collaborative Project
Web address: www.heromat.tf.uns.ac.rs

GOTHIC TIE ROD ANCHOR DESIGN: REPRESENTATION AND STRUCTURAL EFFICIENCY OF NORTHERN EUROPEAN ELEMENTS

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KEY WORDS: Structural design, Tallinn, Masonry buildings, Tie rod anchor, Gothic

ABSTRACT:

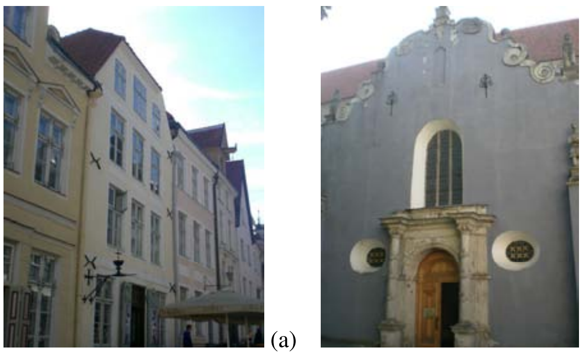
This paper aims to provide knowledge and help discover types of Baltic buildings, by recognizing and understanding their structural elements. The presented approach allows generating a recognizable spatial configuration of the structural ornamental elements that are traces of the past and re-presentation of the same line today. Tie rod anchors contemporaneously have a historical, aesthetic, formal and structural role. Their structural behavior is analyzed producing digital models. Results show the high quality of the element Gothic design, of essential historic importance, and their more structural efficiency than traditional Italian bar shaped tie rod ends. It is shown how, maintaining their formal, historical, representative value, the tie rod anchor structural functionality is increased due to the particular northern European local craft manufacture. The results presented in this paper are based on work developed with Giuseppe Faella, Full Professor of Structural Engineering at the Second University of Naples.

1. INTRODUCTION

Tallinn, European Capital of Culture in 2011, has planned manifestations on the 'Stories of the Seashore' i.e. on the legends inspired by Estonian sailors. In the European manifestation that began in 1985, Tallinn and Turku in Finland were the protagonists of a movement that attracted a lot of important names in international culture, showing creativity that can be seen in the city alleyways in the best possible way. The excellence of this place inspired the study to focus on the journey of knowledge to preserve the historical and formal features of northern European design. The development of new conservation techniques is accompanied by the discovery of new mechanical and physical properties of materials that are more hardwearing and durable than traditional materials. The objective of the research is to demonstrate how the use of traditional materials such as wrought iron, typical of Northern Europe, continues to provide an efficient response to the behavior of the structure. It preserves functionality and, at the same time, respects the interesting and peculiar aesthetic, historical and formal tie rod anchors, helped by the particular form of decorative design capable of performing the distribution function of forces. The tie rod anchor has marked the history of this town and, over time, has become a distinguishing feature and attractor for these places. This paper relates to the study on the tie rod anchor efficiency in masonry structure, while anchor plate modelling experimentation on the northern European (Stockholm) has been progressing, for a long time, at the BENECON laboratory of the Second University of Naples, School of Architecture.

To preserve the morphological, aesthetic and historical aspects of design, assessment of the increase in the efficiency of the element anchor plate, shows that the Gothic, symbolism characteristic involved in the breakdown of the pulling force of the anchor plate on the wall is more efficient than the traditional form of European bar shaped tie rod end. Art design in northern Europe resumes the ancient craft. There, this term covers all fields of human action (architecture, urban planning, sculpture). In Italy this term is only used in the industrial field. During the Industrial Revolution in 1700, high philosophy became positive empirical philosophy. A practical turn that took place in the political culture led to capitalism, liberalism and, on the material level to the invention of machines that meant that everything that until then had been made by hand could now be produced by machines. The result was the production of large quantities at the right price.

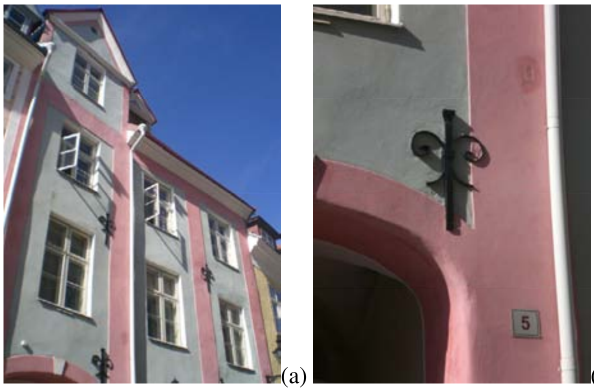
After there was a return to the Middle Ages with arts and crafts whose motto was "the joy in the labour", which rejected contemporary fashion and produced a losing fashion against the business activity. Morris himself, some years later, realized that one should not hinder the industrial machine but should qualify the new product on the basis of an aesthetic tradition rather than copy the recent past. This did not constitute a revival of the Gothic itself, but many artists and sculptors were dedicated to the arts applied to the art of design manufacturing. This is the inspiration for this research. The quality of northern European craftwork steeped in culture of design quality, together with structural efficiency, are aspects that empirically found a response to the excellent speeches held in small towns where they were not fascinated by the "fast industrial design machines" but have kept the traces of art rules and made this the driver of local marketing.



(a) (b)

Figure 1: Tallinn: retrofitted building in old town (a), retrofitted sacred building in old town (b)

Figure 2: Tallinn: wall of the old town



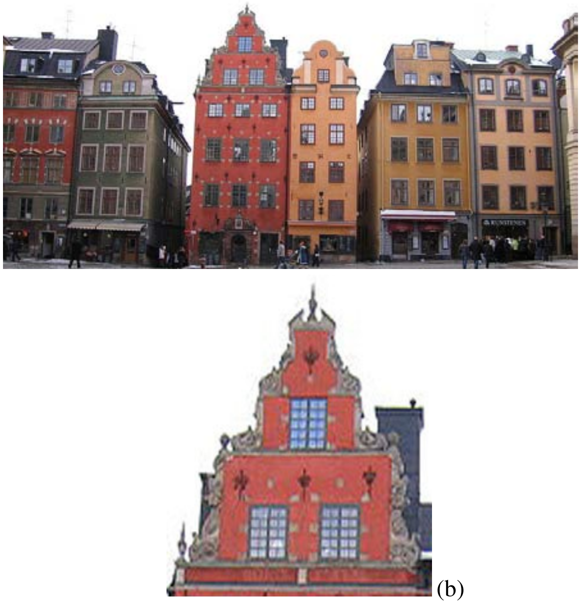
(a) (b)

Figure 4: Tallinn: building in old town (a), tie rod anchor (b)

2. BALTIC ARCHITECTURE AND STRUCTURAL DESIGN OF GOTHIC BUILDING

A particular meaning of Gothic or Gothic-German architecture is one that developed in Northern Europe between the thirteenth and fifteenth century. The countries involved in this type of medieval architecture were in the north of the Holy Roman Empire, Teutonic settlements and citizens of territories of the Hanseatic League. The characteristic of the buildings in Northern Europe was the use of clay, different from that adopted by French Gothic. In addition to church buildings and the Church of St. Mary Lübeck in Germany, with its slender forms that was considered a landmark for several centuries, in northern Europe found space on buildings with dark red brick facades, fancily decorated with figures abstract geometric inserts and plaster to create a clear contrast. Facades are like business cards for the observer that cannot imagine the interior of the building but is captured by those particular identification details.

Heinrich Brunsberg, a famous Baltic architect developed a virtuous theme of brick decoration between the fourteenth and fifteenth century. The design represented by anchor plate being studied, recalls the issue of quality at a fair price compared to that notion that objects should only serve their function. These are not industrial design objects, but objects that are of a different identity depending on their location.



(a)

(b)

Figure 3: Stockholm: Stortorget sq. in Gamla Stan district (a), building façade (b)

3. VIEW OF THE CITY OF TALLINN BY RECOGNISING TIE ROD ANCHORS AND STRUCTURAL ELEMENTS. ANALYSIS METHODS

Obtaining information on site, from a visual to photographic analysis and via metric relief up to investigation with non-invasive instruments, are part of a process phase that can be defined by the concept of knowledge. Being kidnapped by feelings that an urban environment like that of Northern Europe can result in visiting those places, is something to be reckoned with in the recognition of characteristics territorial values of every places. The Multicriteri@ approach used for the preparation of this paper is something that goes beyond simple information that represents a network of true statements analyzed by different professionals: a multi-disciplinary approach with lists of information and links that result from the critical analysis of relationships between them. “Knowledge management" of the building elements, the object of this research, meant primarily representing and providing a supporting container, knowledge of the characteristics of the aesthetic, formal elements. This representation has meant that geometric elements of reality could be transmitted and could be studied on computer media in

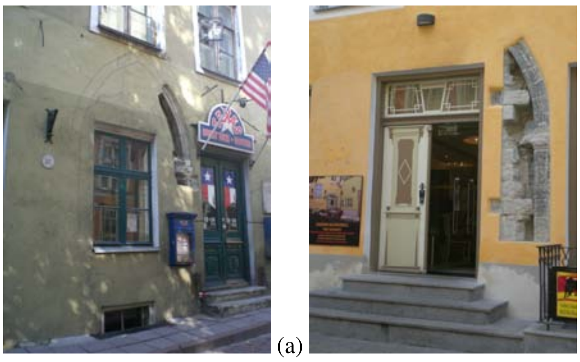
(a) (b)

Figure 5: Tallinn: Building in old town (a), building façade with Gothic tie rod anchor (b)

Figure 6: Traditional Gothic tie rod anchors

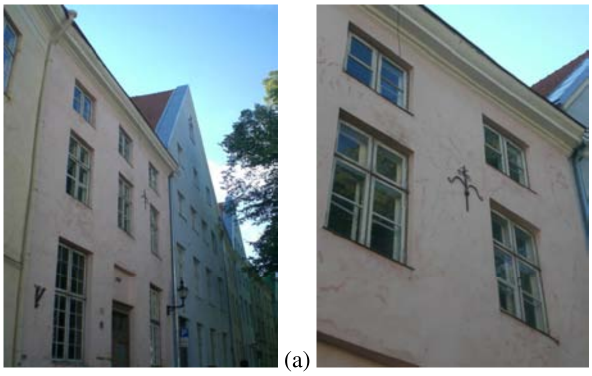
the laboratory. The intuition, study and experience that have accompanied the cognitive path of the anchor plate element, has reduced the complexity of the analysis of structural behavior.

The multi-disciplinary approach has made every brief observation fundamental, from a historic one to multi-media and the single element has become part of the whole picture. The knowledge phase of the anchor plate is complete and necessary information was collected. On then passed to creating a method of analysis attentive to structural effects derived from particular design forms, rather than fulfilling functionality. In The Architectural Record, May 1937, Gropius alludes to the true form of architecture, claiming that the "features equally beautiful" slogan is half true. There are elements such as the North European anchor plates that are charming as they are incorporated into a valuable, balanced, historical context. Functionality is linked to beauty in context and proportion. This is the strength of the object of this investigation. It has to be asked the reason for which an element created to fulfil a purely



(a) (b)

Figure 7: Tallinn: retrofitted building in old town (a), traces of original structure: façade detail (b)



(a) (b)

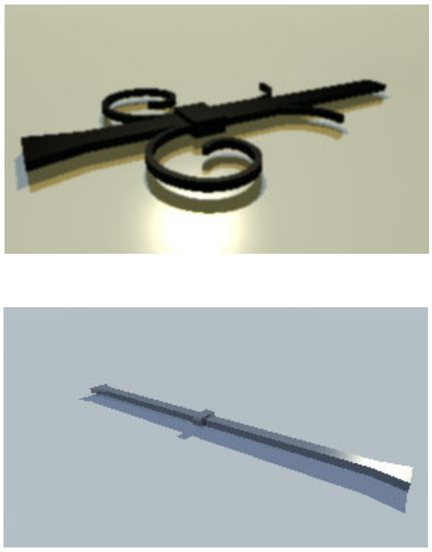
Figure 8: Tallinn: retrofitted building in old town (a), tie rod anchor (b)

structural function, over time, has managed to acquire a significant role to become a point of attraction of local marketing.

4. STUDY ON GOTHIC AND MODERN STYLE TIE ROD ANCHORS

The structural behavior of the shaped tie rod anchors, and specifically how the two curled elements contribute (with the main stake) to the resistance was performed by a nonlinear static analysis on the masonry tie rod anchor complex. The analysis was performed using a finite element modelling, and both masonry and steel components were modelled using six and eight nodes solid elements. Figures 10 and 11 show the mesh used for discretizing the tie rod anchor elements and the portion of the rear masonry wall in the presence or absence of the two curls respectively.

The orthotropic material properties proposed by Pande et al. were used to model the masonry structure in the sense of an equivalent homogenized material, based on a strain energy



(a) (b)

Figure 9: Virtual model reconstruction of northern European wrought iron tie rod anchor (a), virtual model reconstruction European bar shaped tie rod end (b)

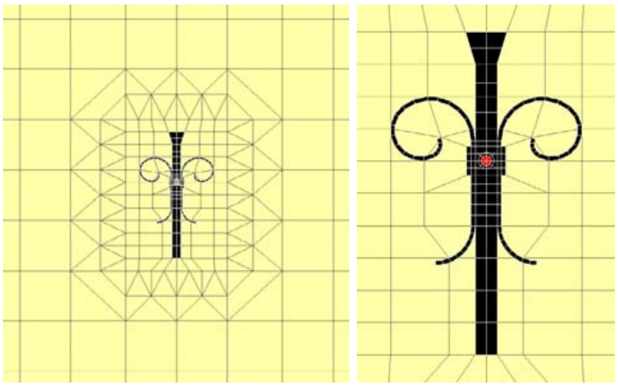


Figure 10: Mesh of tie rod anchor with the two curled elements

concept. The basic assumptions made to derive the equivalent material properties through the strain energy considerations are. (i) bricks and mortar are perfectly bonded, (ii) head and bed mortar joints are assumed to be continuous (therefore, the assumption of continuous head joints instead of staggered joints, as they appear in practice, is assumed to not have any significant effect on the stress states of the constituent materials). Consequently, the orthotropic material properties are function of the brick dimension (length, height and width), thickness of mortar joints, Young's modulus and Poisson's ratio of brick and mortar. Typical values of ashlar masonry with medium-low resistance were used in performing the nonlinear analysis. Namely, brick/block length between 200 and 300 mm, brick/block height between 80 and 120 mm, thickness of mortar bed of 10 mm and thickness of mortar head equal to 5 mm were assumed. The masonry units were supposed to have compression strength f_{bc} equal to 3 MPa, tensile strength f_{bt} = 0.1 MPa, Young's modulus E_b = 2000 MPa, Poisson's modulus equal to 0.15. The mortar was assumed to have compression strength f_{mc} of 1.5 MPa, tensile strength f_{mt} = 0.05 MPa, Young's modulus E_m = 1500 MPa, Poisson's modulus equal to 0.10. A volumetric mass equal to 17 kN/m^3 was finally assumed.

The failure of masonry is then based on a micromechanical behavior. At every loading step, once the equivalent stresses/strains in the masonry structure are calculated, stresses/strains of the constituent materials are derived based on their structural relationship. The maximum principal stress is calculated in each constituent level (brick, bed and head joint) and is compared to the maximum tensile strength. If the maximum principal stress exceeds the tensile strength at the current step, the stiffness contribution of the constituent to the whole element is forced to be negligible. In this way, the local failure mode can be evaluated. Once cracking occurs in any constituent material, the effect is smeared onto the neighbouring equivalent orthotropic material through another homogenization.

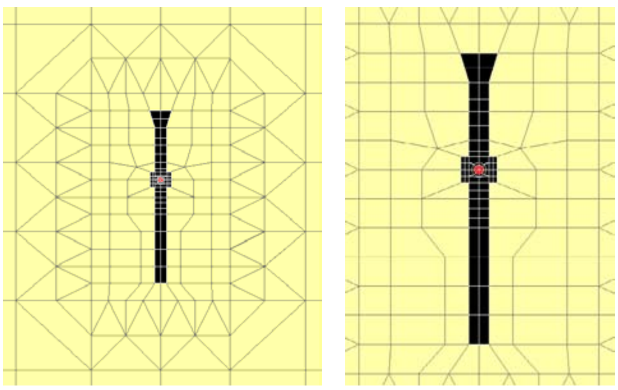


Figure 11: Mesh of tie rod anchor without curled elements

The well-known and widely used yield criterion by Von Mises based on distortional strain energy was used for the steel elements. A yield stress of 360 MPa was assumed for both the tie-rod and the tie rod anchor.

The contribution of the two curled elements to the resistance was evaluated by comparing the response in terms of bearing capacity and stress state on the masonry, considering them present or not. The nonlinear FEM analysis showed that the presence of the curled elements does not contribute much in stiffening the tie rod anchor and limiting the maximum stresses on masonry, but significantly influences the masonry area involved by local pressures. Figures 12 and 13 show the deformed shape of both the considered tie rod anchors at a loading level corresponding almost to the maximum one borne up by the masonry. The figures show that in both cases the tie

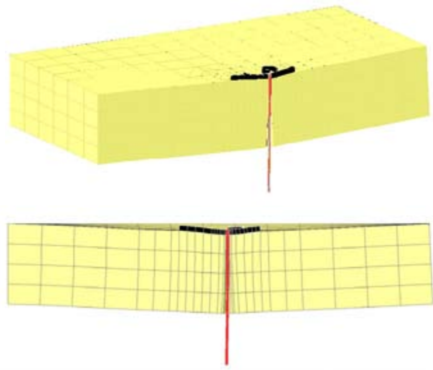


Figure 12: Deformed shape of the tie rod anchor with the two curled elements

rod anchor presents a significant bending, with a variation in displacement between the ends and the tie-rod connection point (where the displacement is maximum and equal to 0.41 mm) of approximately two-tenths of millimetres.

Therefore, high stresses are registered on the masonry at the

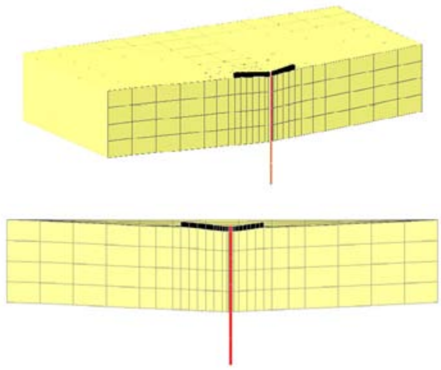


Figure 13: Deformed shape of the tie rod anchor without curled elements

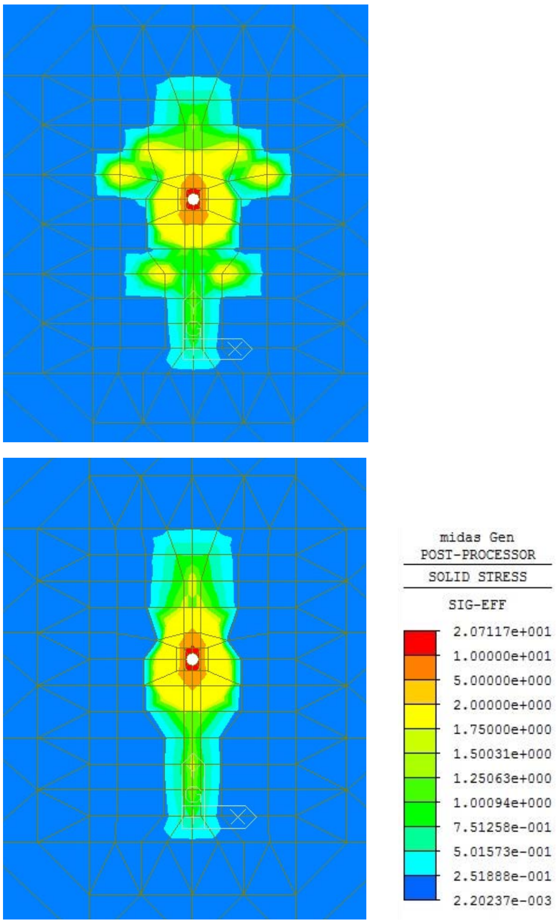


Figure 14: Effective stresses on masonry lying behind the tie rod anchor with and without the two curled elements


(a)
(b)

Figure 15: Tallinn: retrofitted building in old town (a), bar shaped tie rod end (b)

connection of the tie-rod, as shown in Figure 14 where the effective stresses on the masonry wall are plotted at the same loading level of Figures 12 and 13. Then, as it is expected, the stresses around the masonry hole imply local failure of masonry, only partially allowable. Figure 14 instead shows average stresses on the masonry portion involved by the tie rod anchor that are bearable by masonry itself, and, above all, clearly confirms the larger capability of the shaped tie rod anchor with curled elements in distributing the pressure on masonry.

5. CONCLUSIONS

Johann Wolfgang Goethe in the "Writings on art and literature," says that art must be able to represent nature by imitating it without knowing it and presenting it in its own way. The style of an artist is formed when the universal element of nature is represented and it causes what is termed as emotion dictated by the rules of art. These are the foundations of the ancient Northern European craftsmanship that add emotion to make use of the stylized nature of the object (leaf, flower, branch), the elevated aesthetic and historical value and the skilful technical intuition of structural efficiency. The Rules of Art are recipes to be preserved as a basis for progress in the right direction.

They successfully combine knowledge of the structural Cartesian “tie rod anchor” and the symbolism attached to it in the Gothic period and lead to an integration of reasons for its simple response to stress with reasons for its Leibniz shape (intensive, internal and romantic). In the Baltic Gothic period, geometric and mathematical thought unites with typological and morphological thoughts. The drily defined rod becomes recognised as an element, a symbol of belonging to a noble decoration. The streets and houses in Stockholm and Tallinn express their story through the structural elements that become intensive. The emphasis of the facades and structural

Figure 16: Decorated wrought iron tie rod anchor

strengthening systems combine to create new contexts in ancient systems. Modern urban design choices lead to careful study of philological structural elements, bearers of history. Critical reading of a typical prospectus of northern European cities reacts with theories and urban programs that cancel the past and in a modern way protect the signs of a cultural antecedent. Tallinn, Kultuur kutsub 2001 (Culture European Capital in 2011) fully describes the intelligent urban renewal project, resulting from careful and thorough study of morpho-typological importance of structural elements. Being able to use new technologies to ensure the protection and safety of the cultural heritage is essential to maintain the identity of a place. The efficiency that quality traditional crafts material can provide in terms of long term durability, minimizes maintenance time and allows one to monitor structure degradation. The proven efficiency of the Gothic shaped tie rod anchor, raises the role of this structural element that becomes a symbol of a community and does not just fulfil its technical task.

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THE PORTICO OF THE CHURCH OF ST. FRANCIS IN URBINO: A DIGITAL MAP FOR MONUMENTS

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KEY WORDS: 3D MODEL, CONSERVATION, HISTORICAL MONUMENTS, DIGITAL MAP, PHOTOGRAMMETRY, LASER SCANNER

ABSTRACT:

This paper describes the preliminary study for restoration works on the portico of the Church of St. Francis in Urbino. The aim of this study is to develop models used for restoration works on the surfaces of the portico, based on a prior architectural survey using different methodologies. The research project was carried out in 2 phases: during the first phase quantitative data were obtained by means of formal-geometric surveys and during the second phase qualitative data were obtained by developing models. Results were diversified according to needs and the methods used in order to create a "digital map of the monument" in its context. In the last phase, the various methodologies were analysed and compared in order to evaluate their accuracy, convenience (in terms of times and costs) and application limits.

1. INTRODUCTION

One of the most important presuppositions of conservation is the respect afforded not only to the work of art but also to the historical data relating to the same, thus considering the work of art in its diachronic evolution, by interpreting and recognizing the building as a whole.
Conscious choices may in this way be made, and only with correct documentation is it possible to conserve and allocate new functions to architectural monuments.
The project entailed enormous responsibilities and was handled in an objective, scientific and correct manner, using all the tools of knowledge available, from historical analysis to metric surveys, from topography to the study of materials and problems of degradation, using a combination of professional skills and expertise.
The problem of survey and representation in restoration and conservation of buildings has become increasingly important over the years since it is seen as a means of investigating and organizing data in order to understand an architectural work or archaeological site.
Metric data are undoubtedly represent the first level of knowledge so that the scope was to quantify the data in a specific space.
Once data have been gathered, they may be used in other fields, as support for qualitative or historical-typological data for example and as a basis for the management of protection and planning, with the use of appropriate tools.
Survey and representation of buildings, using different methodologies and tools, means bring to the fore an activity which today involves various operators and must be interpreted by means of clear and common symbols, signs and graphs.
In these research activities as a whole, the survey is an "open system of knowledge" that ranges from the details of the single element to the organism as a whole, analysed constantly with respect to its environmental context.
The survey techniques are described in order to obtain a correct and metrically accurate representation of the building, taking into account the quality and possibility of verifying the survey in terms of interpretation, evaluation and representation of the object.
The survey must be structured as a set of differentiated and organically linked techniques and must be organised in phases, with operations ranging from general to detailed evaluations*.
Results were diversified according to needs and the methodologies used in order to create a "digital map of the monument" in its context, used as a basis to develop the following aspects:

- control and monitoring of the transformations that take place in both the natural and urban environment due to the actions of man and/or nature;
- preventive surveys on monuments in highly urbanized areas;
- simulation of interventions on 3D models.

Figure 1: View of the Portico of the Church of St. Francis in Urbino

* BIANCHINI M., Manual of digital documentation and survey in archaeology, Rome 2008, page 9-20.

2. SURVEY AS CARTOGRAPHIC BASE TO SUPPORT RESTORATION

In this sense, the survey must be considered as a field that makes use of all and any sciences and techniques that may help to interpret, measure and analyse the evident and hidden morphological, material and structural aspects of an object.
Definition in object rendering may in this may be directly associated to an investigation of the following phases:
1) Topographic survey in order to determine the geometric reference structure with respect to detailed surveys (photogrammetry and laser scanner), guaranteeing the planned level of precision of the survey and include the following:
a) construction of a topographic framework network by means of a total station;
b) construction of networks, anchored to the previous network, which metrically locate the details ensuring the topographic basis for the survey of points that are not accessible to direct readings as well as supporting points for photographs;
c) execution of topographic branching anchored to the previous networks, to determine the peripheral points not accessible to the polygons;
d) topographic determination of supporting points with respect to the photographic and/or photogrammetric shots;
e) accurate planimetric and altimetric compensation of topographic readings;
2) 3D Scanning. This entails acquisition of metric and deformed data by means of a laser ray surveying device. The scanning sensor, which is mounted on a motorised base, generally works within a horizontal range of 360° and a vertical range of 180°, and records all the visible architectural points (with respect to the scanning centre), at an angle which may be adjusted by the user. As in the case of topographic surveys carried out with total station, this survey system must be collected to a polygonal network, but with a higher number of points entered and recorded. A 3D point cloud is obtained which precisely reproduces the state of the object, and permits solid modelling. This technique may be used for all elements that are difficult to access or measure and may be considered as an experimental approach, verifying its quality, times and costs.
3) Photogrammetric Surveys These are used to construct 3D models which are useful for rendering internal surfaces and also provide accurate complete documentation of the actual conditions. 6x6 cm and/or 24x36 mm professional cameras and/or semi-metric mono-cameras, which are suitable for 6x6 cm photogrammetric rendering, or the more commonly used digital cameras, may be used. Shots should be taken at a distance compatible to the rendering scale, with horizontal and vertical overlapping of the strips by at least 10% and successive cataloguing of photograms and models (including the orientation data of the same) and, in any case within the limits permitted by the morphology of the places.
4) Photographic surveys and digital photomaps. High resolution semi-metric and/or digital and professional cameras are used. A sufficient number of shots should be take to cover the entire survey area, on a general and detailed scale. The survey will be useful both for general documentation and to take digital photomaps and digital rectifying mosaics, with specific software using topographic and 3D scanner points.
5) Processing of data and line rendering. In the first phase calculations are performed to minimize data acquisition errors (accurate compensation of polygons), standardize data (roto-translations) and convert all the data to numeric format (digital). In the second phase the data acquired are rendered with the definition suited to the representation scale in question according to the methods and printouts used.

2.1 Survey Phases

Because of the particular features of the structure and the fact that it is located in the city centre, the study and survey project of the structures of the portico required a great deal of work, both to acquire and process data. Work was carried out in two separate phases:

1) Data acquisition:
- Topographic survey
- Photogrammetric survey
- Laser scanner survey

2) Data processing:
- Rectification and construction of photomaps
- CAD processing of photomaps
- Processing of a number of photogrammetric shots with Image Master
- Processing of laser scanner data with Z-Map and RapidForm 2004

2.1.1 Survey Phases: data acquisition

Architectural findings were measured above all by means of two techniques which are widely used in indirect surveys: total station and monoscopic photogrammetry
One day's work was required to survey the architectural complex using the following tools:
1) Electronic total station Topcon 9001A, angle precision: 1", telemeter: 5 mm without prism, LD laser pointer, data processing software: Mercurio (survey management) and Meridiana (topographic calculations);
2) Sony non metric camera, specifications: DSC-F828, Zeiss lens, focal length adjusted at 4.44 mm and 8 Megapixel sensor.
The topographic survey of the three facades was carried out with the same number of stations (S1, S2, S3) for a total of 62 points.
The photogrammetric survey, in particular on the outdoor facades to be restored, was carried out by anchoring the photographic shots at 34 of the 64 points read with the topographic instrument.
The frames, one respectively for the North and South facades and 6 for the Western façade, were taken without positioning targets and rendered by means of reference monographs.
A second photogrammetric survey was later carried out on the Southern façade, on which a detailed survey was then carried out, in order to process the data with Image Master and compare this with the other methodologies which will successively be described. In this phase, frames of the details were also taken (capitals, arches, column bases) in order to ensure more accurate readings for the CAD drawing.
The laser scanner survey was carried out with a Topcon GLS-1550 laser using time of flight technology (TOF) whereby the distance is calculated by measuring the time from when the laser impulse is transmitted by the instrument, to its return after being reflected on the surface. The Topcon GLS-1500 measures a mesh which is dense with points, known as a "cloud" with scanning speed of 30.000 points per second and maximum capacity of 330 m. In addition, five stations were positioned and the points read were based on the physical details of the object.

2.1.2 Survey Phases: data processing

In the first data processing phase, the frames were firstly "rectified", in other words the radial[**] and linear[***] distortions produced by the camera were corrected.
Photographic rectification makes it possible to modify a photograph so as to simulate the shot with the plane of the sensor of the camera parallel to a reference plane chosen on the photograph, giving a central perspective. The rectified image corresponds to a façade when the object is planar. In the case of typically architectural objects, consisting of different parallel planes it is necessary to scale the sections on the various planes differently using measures which are known in advance. Different techniques and data are therefore required to produce a rectified image:

-geometric techniques: using horizontal and vertical lines
-analytic techniques: using known or distant coordinate points

The rectified image is then scaled appropriately and becomes a metric representation that may be used, in other words, to obtain sizes and distances.[****]
An analytic procedure using Archis 2D Pro software was used, which makes it possible to create frames by correcting a number of unknowns in the distorted image such as rotation, translation and scale factor. The only exception is the North façade of the portico which was rectified with a geometric procedure since the topographic points were not reliable and unsatisfactory for a homographic transformation with the analytic procedure.
The input data used for rectification in analytic mode were the 34 topographic points represented in the reference monographs which were appropriately matched on each frame. In view of the fact that some points read topographically were not reliable, it was also necessary to refer to other points obtained from laser scanner data.
The output data provided good rectification with an estimated error of no more than 6mm. The images obtained were then, "mosaiced" with the same software, reconstructing photomaps of each view examined. The sections processed in this phase were, as far as possible, only flat surfaces, considering that the three-dimensional nature of the octagonal columns of the portico, would have produced considerable distortion. To resolve the problem, the 3D elements subject to significant variations were processed with laser scanner data.
The survey data obtained from the total station and orthophotomosaics were imported to CAD. Considering that the photogrammetric process requires a reference system parallel to the surfaces analysed, it was necessary to carry out rototranslations from the global reference system and scale the image in its original dimensions, in order to position each façade correctly. In this way, all the data refer to a global system and may be managed at any time through a territorial computerised system.
Finally, even without working in 3D environment, it was possible to reconstruct the progress of the portico, anchored at the topographic support points and create detailed views and planes, which are indispensible for obtaining information about the object and positioning the data regarding materials and the condition of degradation.
As previously mentioned, additional photogrammetric surveys processed with Image Master were carried out on the Southern façade of the Portico where conditions were more favourable for this type of experimentation.
Image Master Pro is a photogrammetric software which processes 3D data obtained from stereo images, and generates orthophotos and 3D models. During processing, the limits of photogrammetric systems in general and of this system in particular, were identified. Despite the fact that all photogrammetric systems process 3D data, they do not permit stereoscopic orientation, and in fact the photograph pairs are oriented in monoscopic mode and this introduces an error margin that with traditional stereo restitution equipment is undoubtedly lower, in that the latter permit orientation in stereoscopic mode. Moreover, in the specific case of the Image Master, when the polylines or breaklines are defined on the model, the system permits both self-correlation and manual matching; considering however that in the first case it is very difficult to recognise uniform points because self-correlation entails a high margin of error since it is tied to contingent factors such as morphology and above all, the nature of the surfaces, in some cases it is preferable to opt for manual matching. During orientation, the software operates according to strictly photogrammetric principles, giving excellent results with a very low error margin, but when creating the model the software requires various data, above all it is necessary to define the polylines when there are evident variations in height and significant discontinuity which create considerable inconsistencies between the orientation and data creation phases. It should be remembered however that this software was designed above all for teaching so that is undoubtedly less expensive that other software on the market. One of its most important advantages is that data in .wrml format may be exported, which makes it possible to use the data with other software and in remote mode.
In order to obtain an acceptable model, tests were carried out on different stereo pairs which represented the input data together with the tie points and GCPs obtained from the station. Due to the problems mentioned previously, it was necessary to process the meshes of some sections of the model separately, and these were then exported in .wrml format and processed with RapidForm 2004.
The point clouds obtained by laser scanner were initially imported and read with RapidForm, and then exported to Z-Map in .ply format where they were georeferenced on known topographic points, since the first software did not make it possible to georeference point clouds but only the surfaces. The georeferencing output data obtained showed an average error below 3 cm. The clouds were then again imported to Rapidform where they were cleaned and filters applied, producing a mesh of small sections which were then joined and mapped. Despite the three-dimensional elements present (columns and capitals), the 3D model produced was acceptable, excluding those parts where due to objective problems (pedestrian traffic and parked vehicles) it was not possible to obtain sufficient data.

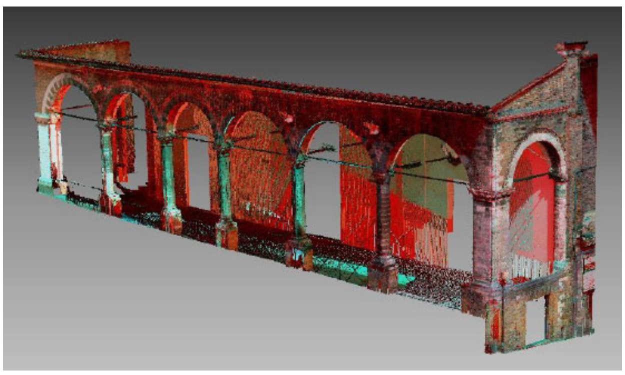
** Radial distortions: due to the geometric characteristics of the lens, the further the object is from the focal centre the greater distortion will be.

*** Linear distortions: due to the position of the shot plane with respect to the object.

**** Bianchini M., op. cit., pages 156-158.

Figure 2: Survey Phase

Figure 3: Survey Phase: orthophoto of the southern side elevation



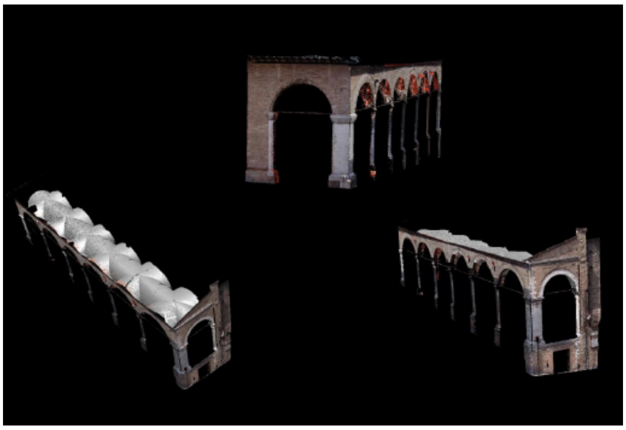


Figure 4: Survey Phase: laser scanner post processing: surface model and mapped model

3. SURVEYS AS SUPPORT TO ANALYSIS OF MATERIALS AND DEGRADATION

This part of the project was carried out on the three facades of the Portico, in order to process tables used as support to the restoration works.
Preliminary knowledge of a building and the materials used in an architectural structure are strictly correlated to a highly critical use of technical and operative tools which should not be separated from an analytical interpretation but must be included in the same methodological programme.
The question of survey and representation in restoration and conservation becomes is seen as a means of investigating and organising data in order to understand an architectural work or archaeological site.
Once data have been gathered, they may be used in other fields, as support for qualitative or historical-typological data for example and as a basis for protection and planning activities, with the use of appropriate tools
In this sense therefore the survey is an "open system of knowledge" that ranges from an analysis of the single elements to the organism as a whole, analysed constantly in its environmental context.*****

3.1 Analysis of Materials

The building materials on the three sides of the portico may be grouped into two main typologies: Furlo limestone and local building bricks; limestone is used on the arcade and upper decorations, the columns and capitals, trabeation and corner blocks while the bricks are used along the section that forms the architectural framework.
White Furlo limestone has excellent technical properties: it may be cut into blocks and used as supporting elements or for decorative detailed elements. It is not have an extremely porous structure nor does it have particularly dispersed bioclasts but since it is a $CaCO^3$ based material it is characterised by all the problems, which will be analysed in more details, that materials of

* **** Docci M., Maestri D., Il rilevamento architettonico – Storia metodi e disegno, Published by Laterza, Bari 1984; Carbonara G., Restauro dei monumenti: guida agli elaborati grafici, Published by Liguori, Naples 1990; Francovich R., Parenti R. (by), Archeologia e restauro dei monumenti, Florence 1988.

this kind have, above all when exposed to heavy pollution or acid rain.******

3.2 Analysis of Degradation

The types of degradation given as examples in the materials and degradation tables may be summarized as follows:

-*Erosion*: removal of material from the surface by different processes. When the causes of degradation are known, terms such as "erosion due to abrasion" or "erosion due to corrosion" (mechanical causes), "erosion due to corrosion" (chemical and biological causes), "erosion due to wear" (man-made causes)" may be used. On exposed surfaces, this kind of degradation most affects sandstone and limestone as well as the mortar layers (rough coating, undulation and plastering) of surface protections (intonachino plaster finish and paint enamel). More specifically, white Furlo limestone is the material most subject to erosion caused by acid rain (ph<5,6) and the action of carbonic acid (H_2CO_3) on calcium carbonate (C_aCO_3) which transforms into calcium nitrate $C_a(NO_3)_2$, causing the carbonates to dissolve.

-*Flaking*: this type of degradation causes total or partial detachment of sections (flakes) of the original material, often close to gaps. The flakes, which consist of material which is apparently unaltered, are irregular in shape, thick and patchy. "Efflorescence" or "biological patina " may be present under the flakes. This type of degradation also affects stone materials in nature, for example manly limestone flakes are commonly found in layers exposed to weather agents. Furlo limestone is again the material with most peeling due to the action of acid rain and progression of erosion.

-*Patina*: An alteration strictly limited to natural modifications of the surface of the material not caused by evident phenomena of degradation, which alters the original colour of the material. Alterations induced artificially are generally known as “artificial patina”. The question of treating patinas is one of the main issues of restoration since it also involves colour, to the extent that even mineral colouring and paint are subject in time to the formation of patinas that alter the colour, paint (to a lesser extent), clarity and shade (to a greater extent). When restoring existing colours therefore this type of chromatic alteration must be carefully evaluated in order to avoid the gradual transformation of the colour in the urban environment. Patinas on the limestone of the Portico are due essentially to hydrocarbon deposits (smog) that accelerate aging of the surfaces generating significant colour changes.

-*Presence of oxalates*: Transformation of calcium carbonate into calcium sulphate in the presence of water and polluting air gases with high sulphate content (sulphur dioxide and nitrogen oxide, the latter of which leads to the formation of soluble calcium nitrate) caused by car exhausts, domestic central heating and industrial factories. Polluting deposits on wall surfaces carried by rainwater, environmental humidity and wall capillarity lead to the formation of these hygroscopic decaying salts which rapidly disintegrate materials, producing whitish and yellowish colour changes, like those on the right hand column of the Southern façade of the Portico.

- *Peeling*: In the case of natural stone materials, peeled parts often have specific shapes according to the structural characteristics and texture, so that terms such as crust, flaking and exfoliation are used to describe them. Peeling may appear as the separation of the undulation from the support, the plaster from the undulation, the plaster finish from the plaster or adhesion between overlying diachronic plaster laid at different times. The most evident peeling is on the bricks on the upper section (peeling on the bottom section of the side pillar is not investigated since this will not be restored).

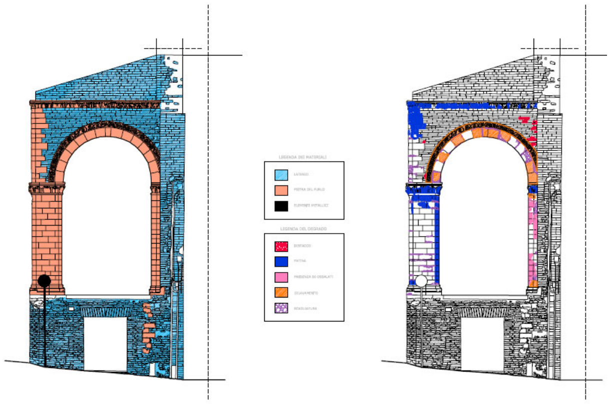


Figure 5: Analysis of materials and degradation

4. CONCLUSION

The main purpose of this project was the creation of a “digital map of the monument” to be used as support for the restoration of the surfaces. Different methodologies were used to produce a representation of the product that was as faithful as possible, emphasising the problem of quality and the possibility of verifying data both in terms of interpreting the object and in terms of measuring and representation. The aim was therefore not to find the most reliable system, but to develop a survey structured as a set of differentiated and organically linked techniques.

The problems encountered were the low level of precision of the topographic survey and the inadequate representation of the same in the reference monographs, which were resolved as described previously.

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INFLUENCE OF ENVIRONMENTAL CONDITIONS AND APPLICATION OF CLEANING METHODS AGAINST BIODETERIORATION OF MARBLE MONUMENTS

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KEY WORDS: marble, environmental conditions, biodeterioration, cleaning.

ABSTRACT

The aim of this paper is the study of the effect of environmental factors on the deterioration of marble monuments and the selection of a suitable and effective cleaning method. One of the main deterioration problems of the monuments is biodeterioration. It was obvious the presence of thick layers of biological patina, covering all almost surfaces of these. The growth of microorganisms, bacteria and plants is enhanced from the particular environmental conditions, that combine increased moisture, insolation and temperature, an area full of plants and trees and can cause extensive chemical and mechanical decay of the monuments. The growth of microorganisms, bacteria, plants and lichens was observed and determined. The influence of specific weathering agents and factors to the behavior of the materials was examined. The chemical composition of bulk precipitation and also the physicochemical characteristics of the surface and underground water were investigated. The environmental conditions and the growth of physical microorgamisms on the surface of the materials led to loss of the structural cohesion and the surface instability of the building materials. A series of various mechanical and chemical cleaning methods were tested in the laboratory containing the use of distilled water, microsandblast, organic solvents, absorbing clays, NH_4HCO_3 solution, biocides (desogen, hydrogen peroxide). In situ tests were carried out with satisfactory results in the monuments when a method of combination of hydrogen peroxide solutions, EDTA, NH_4HCO_3 solution and organic solvent was applied in various steps on the monument surface.

INTRODUCTION

Deterioration of historical monuments is the result of chemical reactions of polluted air, soil and water with the stone building materials. The crystallization and hydration of weathering products result in their expansion causing the degradation of dolomite, limestone, marble, sandstone and other building materials. In most cases the stone surfaces are gradually covered by salts and black crusts containing calcium, magnesium, sodium, potassium sulphates, nitrates and other constituents. Also water can easily penetrate and remain into the building stone materials, resulting in a destructive influence due to the absorption and evaporation of the moisture that affects their volume and causes cracks leading to the deterioration of the structure (Young 2008). Under these conditions, the stone surfaces disintegrate into powder and the building materials gradually lose their mechanical strength and their artistic form (Price, 1996; Winkler, 1997; Lan et al., 2005; Skoulikidis, 2000; Moreno et al., 2006). In the case of marbles the main mechanism of deterioration is the sulphation of their surfaces, leading to the formation of gypsum layers on the stone surface, due to the solid state diffusion of Ca^{2+} (Camuffo et al., 1982; 1983; Del Monte et al., 1984; Rodriguez-Navarro et al., 1996; Keatings, 2007; Simao et al., 2006; Sharma et al., 2007). The deterioration of rocks that are exposed to the atmosphere is a continuing, composite and complex procedure due to physical, chemical and biological processes. The presence and activity of microorganisms in organic or inorganic materials have resulted in the recommendation biodeterioration. The degree and type of damage are related to the climate of the region of development of the microorganisms (nature of mineral, organic material, etc.). Organisms such as algae, bacteria, fungi and animal organisms when deployed in urban areas or in the countryside, on the surface and inside the building material of monuments contribute, depending on the type of organism, with chemical and/or mechanical processes in the biodeterioration of the material.

Biodeterioration of marble includes physical and chemical processes. The accumulation of micro-organisms in the surface of the stone and existing small wells, exacerbates the damage with physical or chemical procedures. Mechanical fracture and dislocation of the structure of minerals is caused due to pressure, which comes from the development of organisms or their parts (roots). This is important when the organisms or micro-organisms do not restrict the size of the surface, but penetrate drastically in the material. Also indirect mechanical actions are induced, especially during frost phenomenon: absorption of humidity, expansion and contraction of the gelatinous canisters that characterize most land forms e.g. algae, resulting in changes of environmental conditions and alteration of substrate. Organisms and microorganisms secrete from their roots acids (strong or weak) which react immediately with the rock corroding mineral, forming complexes salts or destroying it.

Lichens and bryophytes are resistant organisms, suffering long periods of moisture without being destroyed. They absorb, store and desorb rapidly humidity, depending on the environmental conditions. They do not have a root system, but they have strong mechanisms for snapping in the substrate. These properties make them the most dynamic colonists of the building materials of the monuments. A porous surface is more favourable to colonization. The effect of lichens and bryophytes on the monument depends on the specie, the nature and chemical composition of the substrate. Many lichen or bryophyte species retain humidity in the snapping area, causing physical and chemical alterations of the substrate. Many lichens secrete oxalic acid, produce organic acids (by-products of metabolism) and carbon dioxide, leading to chemical corrosion and deterioration of the material (Ahmadian et al., 1983; Ascaso et al., 1994; Sawidis et al., 1995; Scagel et al., 1965).

The historic cemetery of Drapano on Kefalonia island, Greece, was founded during the 6^{th} decade of the 19^{th} century and contains monuments of a great historic, artistic and aesthetical importance. The monuments, plates, reliefs, columns, crosses, busts, reliquaries, statues, with historic inscriptions on theirs surfaces, were made from marble and stone and most of them were built during the last decades of 19^{th} century. The marble used for the construction of the monuments was from Naxos island and the stone from a topical region of Kefalonia; Markatou (1994), Kounadi (1985), Tzouganatos (1996). The cemetery is situated in an area near the sea, full of plants and trees, combining increased moisture, insolation and temperature and presence of organic compounds. These particular environmental conditions enhance the growth of microorganisms, bacteria and plants that can cause extensive chemical and mechanical decay of the monuments. It is obvious the presence of thick layers of biological patina, covering great parts and even all almost surfaces of these. So, one of the main deterioration problems of the monuments is biodeterioration.

EXPERIMENTAL

A series of samples were collected from three different marble monuments. The chemical analysis of the bulk and the surface of the samples was carried out by the Energy Dispersive Spectrometer (EDS-LINK AN 10/55S) of the Scanning Electron Microscopy (SEM) and the mineralogical analysis by X-R Diffraction (Philips diffractometer, CuKa radiation, Ni filter, 2 $=3^o$-53^o, with ASTM cards of the International Centre for Diffraction Data). Samples with various microorganisms were collected from different sites and marble monuments. The locations of sampling were selected based on macroscopic observations about the kind of organism, the type of decay of the material, the distance from the ground, the orientation of the surface and the moisture of the material. The samples, after suitable treatments, were examined macroscopically and microscopically. Twelve samples of bulk precipitation were collected on a monthly basis using a bulk precipitation collector located in the archaeological area for a period of one year. Twelve samples of sea and surface waters were also collected from the neighboring lagoon and a rillet, passing near the archaeological area. Upon receipt in the Laboratory, precipitation and water samples were filtered through 0.45 µm pore diameter cellulose membranes to remove particles. Chemical analysis for the determination of the chloride, nitrate and sulphate ions was carried out by Ion Chromatography.

Cleaning

The laboratory cleaning tests were carried out in 3 marble samples.

Mechanical cleaning. All samples were washed with distilled water for the removal of unstable deterioration products. The surface of the samples was cleaned by shooting of thin powder of small bullets (diameter 50-150 µm) of Al_2O_3. The controlled conditions of operation (microsandblast) lead to the removal of the superficial patina.

Chemical cleaning. Organic solvents were used for the removal of fatty compounds.

-Absorbing clays: They have a great specific area and a high ability of absorption of aqueous solutions and they can be used for the cleaning of biological patina and soluble salts. A paste of absorbing clays (sepiolithos) with water was produced that it was applied in the samples for 3 days. The procedure was repeated 4 times.

-NH_4HCO_3 solution. A solution of 7% of NH_4HCO_3 in water with the addition of non-acidic paper, in order to produce a paper-pulp, was used for the removal of the soluble salts. It was applied for 24 hours and the procedure was repeated 3 times.

-Desogen 3-5%. Desogen is a biocide compound and also during the cleaning process decreases the superficial tension between patina and solution, making easier its removal. It was applied for 24 hours and the procedure was repeated 2 times.

-Solution of hydrogen peroxide (H_2O_2) 10-15%. It was used for the removal of the biological patina, due to its strong oxidising properties. It dissolves the colouring substances and the organic compounds.

The last step of the chemical cleaning was the wash of the surface with distilled water and the measurement of pH of the water that is removed from the surface, to confirm that it is the same with the one of the distilled water.

Ultraviolet radiation. Ultraviolet radiation (250nm wave length, 40W lamp, distance from the sample 10-20cm) was used for the removal of the biological patina. It was applied for a period of one week.

RESULTS AND DISCUSSION

From the results of the chemical and mineralogical analysis follows that the material used for the construction of the marbles monuments was the same and is mainly composed of calcite (96-99%), the remaining been quartz (1-2%) and clays (1-3%). The results were similar for both bulk and surface samples of marble. Deterioration problems due to air pollution or acid attack were not observed.

The historic monuments are sited very near the sea. The subsoil of the area consists mainly from permeable calcite rocks. To examine the possible influence of these conditions to the deterioration of the monuments, the physicochemical characteristics of the seawater are presented in Table 1. The results of the chemical analysis of bulk precipitation and surface water for major anions are shown in Table 2 and 3 the climate parameters and conditions are presented in Table 3.

Table 1 Physicochemical characteristics of seawater (annual variation)

Cl- ions (g/L)	Nitrate ions (mg/L)	Sulphate ions (g/L)	
16.3-21.5	0.2-0.9	1.6-2.7	
Suspended solids (mg/L)	Conductivity (mS/cm)	Temperature (t ^oC)	pH
18-31	22-54	13-26	7.5-8.5

Table 2 Concentrations of sulphates, nitrates and chlorides in surface waters and rainwaters (annual variation)

Surface water		
Chloride (mg/L)	Nitrate (mg/L)	Sulphate (mg/L)
300-600	4.7-11.8	25-40
Rain water		
Chloride (mg/L)	Nitrate (mg/L)	Sulphate (mg/L)
140-180	2.5-4.4	10-20

Table 3 Climate parameters

Temperature (t ^{o}C) (annual variation)		
min	max	average
0-14	20-40	11-26
Relative Humidity (annual variation)	rainfall	
64-73	total(per month-annual variation)	Max (per 24h)
	6-150	26-190

From the results of the chemical analysis of the rain and surface waters follows that chlorides exhibited elevated concentrations, suggesting transport of marine aerosol in rain water and salt water intrusion from the sea in surface water. It is also evident that there are not significant amounts of nitrates or sulphates (except the case of nitrate in surface water, due possibly to the surrounding agricultural land). This observation is in accordance with the mentioned results of the mineralogical analysis, where no presence of crystallized salts on the surface or inside the pores of the materials it is observed. Significant variations of the temperature and the rainfall values during the year are observed correlated with dry/wet, cool/warm periods of time.

From the macroscopic observation it is obvious the presence of thick layers of biological patina, covering great parts or all almost surfaces of these. The colour of the patina varies from white, yellow, green or black. Also in some cases layers of unstable corrosion products and black crust are observed. These observations confirm that the main deterioration problem of the materials is biodeterioration, due to the growth of microorganisms, bacteria and plants, enhanced from the particular environmental conditions.

From the microscopic examination of the selected samples of microorganisms follows that the kinds found on the surfaces of the marble or in contact with it are algae (mainly cyanophyta), lichens, bryophytes, vacteria and mikytes. The determined cyanophyta are forms which often found in limestone rock located in conditions of adequate lighting, temperature and humidity and possibly moved and settled in the marble from the surroundings. Cyanophyta and lichens form on the surface of the material visible macroscopic green, orange, yellowish, brown or black overlays and coatings. The identification was based on the study of morphological traits in natural and cultivated material, (Komarek & Anagnostidis, 1986), (Anagnostidis & Komarek, 1988). The qualitative and quantitative microflora composition reveals that the study area of the cemetery with the sculptures is characterized by “eutrophic” and “oligotrophic” areas. “Eutrophic” are the positions that are characterized by a build-up of soil with slow drainage and good development of bryophytes. Such areas were found at the base of statues (terraces), on plates, trenches and wells of the structural material. These positions, since they are rich in organic and inorganic nutrients and moisture, present conditions favourable to establish and develop even higher plants in the future. The greatest variety of cyanophyta species observed is attributed to this phenomenon. In contrast, smooth, flat, dry and uniform chromatic surfaces of material are “ligotrophic” areas of the ecosystem of the monument and show little diversity and settlement of cyanophyta.

The kinds of algae (mainly cyanophyta), lichens, bryophytes, vacteria and mikytes found on the surfaces of the marble or in contact with it and the corresponding photo images are shown in Figure 1 and Table 4.

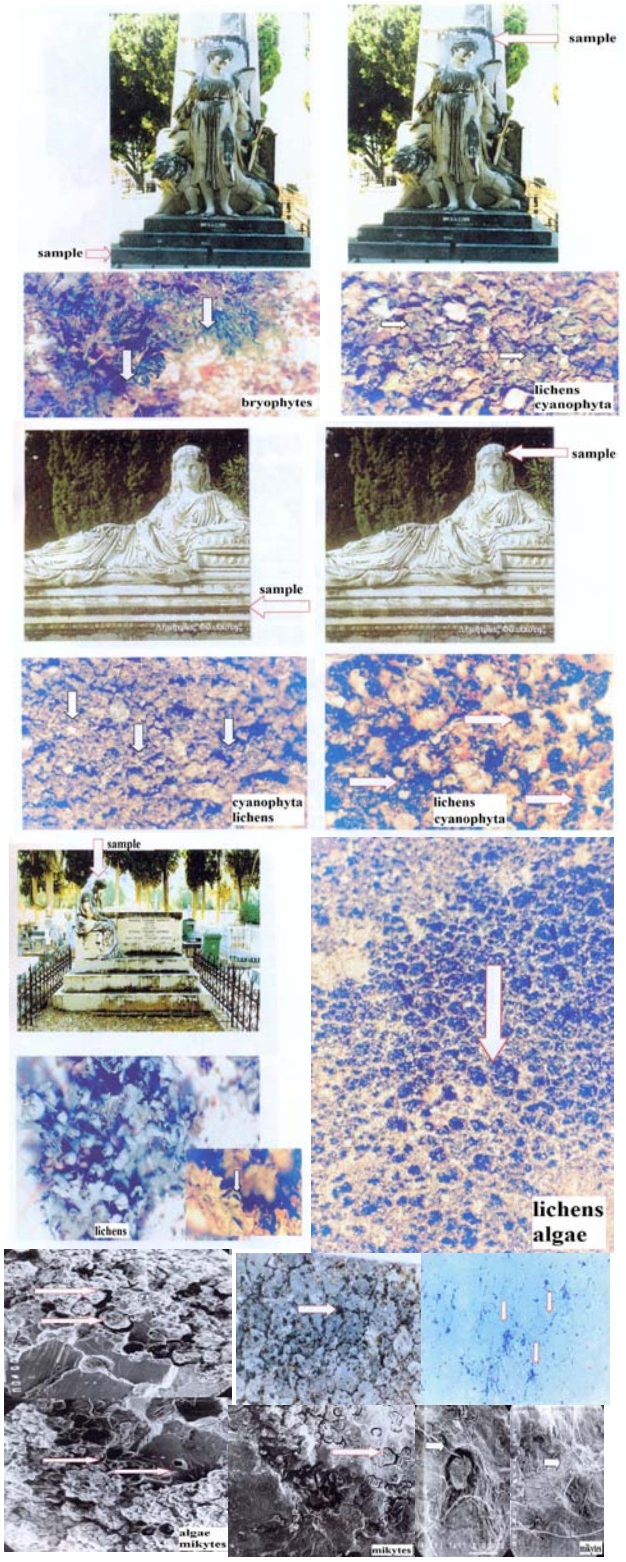

Figure 1 Sampling sites, stereoscope and scannind electron microscopy images of ajgae, cyanophyta, lichens, bryophytes, vacteria and mikytes found on the surfaces of the marble

Table 4 Identification of cyanophyta found in monuments area.

Aphanocapsa sp.	Leptolyngbya cf. boryanum
Aphanocapsa grevillei	Leptolyngbya foveolarum
Calothrix cf. parietina	Leptolyngbya tenue
Chroococcidiopsis sp.	Myxosarcina chroococcoides
Chroococcus minor	Myxosarcina sp.
Chroococcus minutus	Nostoc sp.
Cyanosarcina cocinna	Nostoc spaericum
Cyanosarcina sp.	Oscillatoria tenuis
Chroococcus minutus	Phormidium corium
Chroococcus minutus	Pseudanabaena catenata
Gloeocapsa sanguinea	Schizothrix sp.
Gloeocapsa sp.	Tolypothrix byssoidea
Leptolyngbya angustissima	

The results of the laboratory application of the various cleaning methods on a marble sample are described below. Biological patina covered all surface of the sample, as it is observed in Figure 2a, where the initial situation of the sample it is shown. For the cleaning it was applied, in part of the sample to be obvious the results of the cleaning, distilled water and organic solvents, biocide, hydrogen peroxide, NH_4HCO_3, sepiolithos and microsandblast. The application of hydrogen peroxide removed a first layer of biological patina and after that microsandblast was applied for the total removal of the patina. A kind of yellow patina is observed on the sample, due to the action of some microorganisms that have the ability to remove the ferrous ions from the bulk of the material and concentrate these in the surface where they are oxidised forming yellow ferrous oxides that they are a kind of physical patina and must not be removed. The images of the sample during the cleaning procedure are shown in Figures 2b-2d, (intermediate steps) and Figure 2e, (final situation).

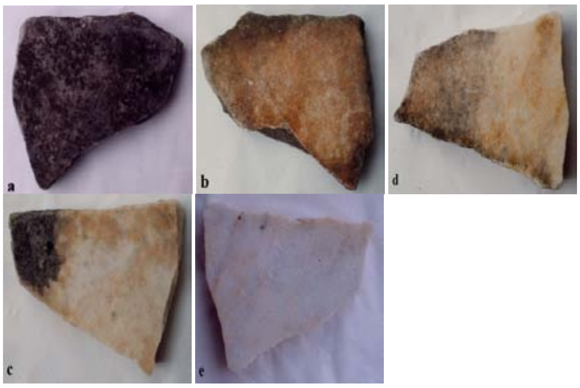

Figure 2 Procedure of cleaning of M_1 marble sample; a: initial situation, b-d: intermediate steps, e: final situation

In situ application of cleaning methods on marble monuments

The monuments where the cleaning methods tested in laboratory experiments were applied are shown in Figures 3a, 4a and also Figures 3b, 4b, where parts of the statues with representative problems of deterioration are shown. From these figures it is obvious the presence of thick layers of biological patina of a green, blue or orange colour, covering great parts of various areas of the statues. In some cases, layers of insoluble salts of brown colour or black crust and also deteriorated parts of the surface with cracks on it are observed. From these observations it is evident that biodeterioration caused serious problems not only on the surface of the statues but also and inside the pores of the marble.

Cleaning Procedure:

Typaldou statue

The initial situation of the statue is shown in Figures 3a,b. After a mind mechanical cleaning with water, a solution of Hydrogen peroxide 10% was used for the removal of the biological patina but with mediocre results. A paste of hydrogen peroxide 25% with paper-pulp was applied for 3-4 hours in areas of thick layers of biological patina with satisfactory results (Fig. 3c). A paste of EDTA 12% was applied for 1 hour for the removal of the layers of insoluble salts and lead to a partial removal of the salts (Fig. 3d). After that the repeated application of a solution of hydrogen peroxide 25% for 5 hours had very satisfactory results (Fig. 3e).

Figure 3 In situ application of cleaning methods on a marble monument (Typaldou statue); a: general view-initial situation, b: detail-initial situation, c-d: intermediate steps, e: final situation.

Kosmetatos statue

The initial situation of the statue is shown in Figures 4a,b (biological patina – black crusts). Mechanical cleaning, spaying with a solution of Hydrogen peroxide 10%, application of a paste of hydrogen peroxide 25% with paper-pulp for 5 hours and application of a paste of EDTA 12% for 2 h for the removal of black crusts were used (Figs. 4c,d)

In the areas where the biological patina was removed, layers of a brown or yellow colour were observed that were removed after a 3 times application of a paste of EDTA 12% for 2 hours. Layers of yellow ferrous oxides, formed due to the oxidation of the mineral iron present in the marble, were observed in some areas in the lower part of the statue after the cleaning. These layers can be removed with an application of compress of a solution of thioglycolic acid 5%, neutralized with NH_3 for 1-2 minutes.

Figure 4 In situ application of cleaning methods on a marble monument (Kosmetatos statue); a: general view (initial situation), b: detail (initial situation), c: intermediate step, d: final situation.

CONCLUSIONS

1. The material used for the construction of the marble monuments was the same and is mainly composed of calcite (96-99%), the remaining being quartz and clays. The results were similar for both bulk and surface samples of marble. Deterioration problems due to air pollution or acid attack were not observed.
2. Chlorides exhibited elevated concentrations, suggesting transport of marine aerosol in rain water and salt water intrusion from the sea in surface water Absence of significant amounts of nitrates or sulphates is observed in the rain and surface waters.
3. The main deterioration problem of the materials is biodeterioration, due to the growth of microorganisms, bacteria and plants, enhanced from the particular environmental conditions with thick layers of biological patina covering great parts of the surfaces of materials.
4. From the various mechanical and chemical cleaning methods tested in the laboratory, the best results were obtained with the use of a combination of hydrogen peroxide and microsandblast. The material of microsandblast was thin powder of small bullets (diameter 50-150 μm) of Al_2O_3.
5. Satisfactory results from the in situ tests in the monuments were obtained when a method of combination of hydrogen peroxide solutions, EDTA, NH_4HCO_3 solution and organic solvent was applied in various steps on to the whole monument surface or part of it, according the kind and the thickness of the patina in the various parts of the monument.

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DAMAGE ASSESSMENT AND CHEMICAL CHARECTERIZATION OF GLASS OBJECTS EXCAVATED FROM GADARA, NORTHERN JORDAN

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KEY WORDS: Gadara, Glass, Diagnosis, Chemical characterization, XRF, SEM, Deterioration, Corrosion.

ABSTRACT:

During the excavation works carried out by the Department of Antiquities, at the archaeological site of Umm Qais/Gadara, Northern Jordan, from January 6 to February19, 2009, a considerable collection of glass objects of different typologies and colors were uncovered in a Roman cemetery. These glasses were characterized chemically by using X-ray fluorescence spectroscopy (XRF) and examined by scanning electron microscopy (SEM). The results indicated that these glasses are of soda-lime–silica type and correspond to the previously defined Levantine I glass group, and dated back to the Roman period (1st-4th Century AD). Furthermore, SEM investigation revealed that those glasses are completely corroded, and subjected to intensive deterioration. Therefore the preservation of those deteriorated glasses was important because of their archaeological and technological interests.

1. INTRODUCTION

The modern village of Umm Qais, ancient *Gadara* during the Roman Empire's occupation of Jordan, is situated 110 km north of Amman (Capital of Jordan) on a broad promontory 378 meters above sea level with a magnificent view over the Yarmouk River, the Golan Heights, and the lake Tiberia (Figs. 1, 2). Gadara was one of the most brilliant ancient Greco-Roman cities of the Decapolise (Weber, 1989; Nielson, 1992).

In 2009, excavation works were carried out in the eastern area of the site representing the Roman tombs (Fig. 3). Excavations uncovered some important and magnificent architectural monuments at the site, such as rock-cut and built tombs in different shapes and structures, in which numerous remains of coins, bones, pottery objects, metal tools, and glass objects were found. Great collections of intact glass objects of different typologies and colors were uncovered from tombs no. 1and 3 (Fig.4). These glasses were recovered together with considerable collections of pottery lambs and metallic coins, which were dated with certainty to the 1st-4th centuries AD. Typologically, they were dated back to Roman period in Jordan (1 st-4th cent. AD) (Abd-Allah, 2010). These corroded glass objects appeared to be a good example of freshly excavated glass, on which several first aid treatments could be carried out in the field.

It was stated that when glass is buried in a water-containing environment, the surface of the glass reacts chemically with the water. Additionally, the amount and type of reaction is affected by the composition of the glass and the pH of the surrounding liquid. It was generally accepted that several parameters influenced the archaeological glasses pathology during burial, like type of glass, burial conditions and the thermal history (Jackson et al., 2012). It is presently thought that a reaction is brought about by the diffusion of water (mainly through H^+ cation exchange) into the glass and the migration of the alkali cations from the glass, leading to a silica-rich layer that is also reduced in density ((El-Shamy, 1973; El-Shamy et al., 1975). The alteration takes place at the surface, but the water also penetrates beyond the visible interface between the altered and pristine glass at a depth that is a function of glass polymerization. This reaction is especially effective in glasses that are rich in potassium.

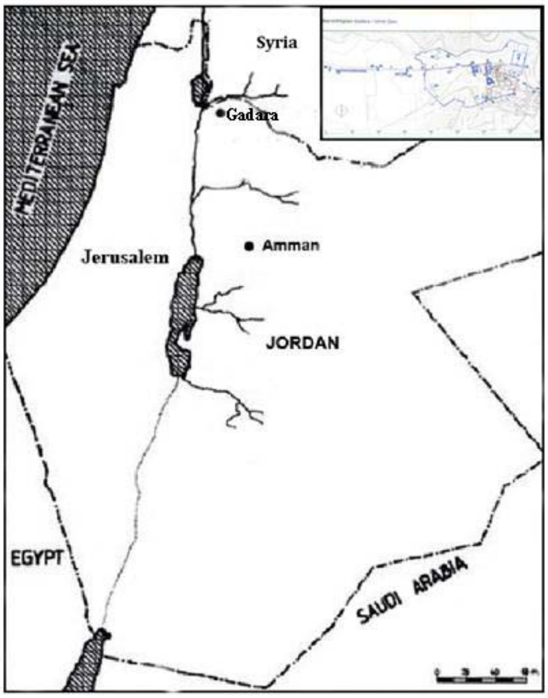

Figure 1: Map of Jordan indicating the site of Gadara/Umm Qais in Northern Jordan.

Figure 2: General view of the archaeological site of Gadara and some architectural remains.

Figure 3: Roman cemetery excavated in the site, season 2009.

This newly formed silica-rich layer acts partly as a protective layer to the glass, slowing the rate of decay. The surrounding aqueous layer then becomes more highly alkaline with the increase in sodium and potassium ions. At pH 9, the silica- (and sometimes calcium-) rich layer is attacked and the process starts again. Thus, the interaction of glass with water involves, or causes, pH changes in the solution, which influences the type and rate of reaction (El-Shamy and Douglas, 1972; El-Shamy et al., 1972; Cox and Cooper, 1995; Sterpenich and Libourel, 2006; Gulmini et al., 2009; Rehren, 2008; Jackson et al., 2012; Abd-Allah, 2012).

However, the high content of soda (Na_2O or K_2O) leads to the process of leaching and corrosion of those glasses during burial in wet environment (Paul, 1977). In leached or corroded glass, there is an obvious change in the compositions of weathered crusts in comparison with the durable glass core of the same sample, i.e., sodium and potassium content decreases, whereas silica and calcium content increases (Newton and Davison, 1989).

The main objective of this study is firstly to characterize the chemical composition of those Roman glasses excavated from the archaeological site of Umm Qais/Gadara, secondly to assess the deterioration state in relation to burial environment and diagnosis the various aspects of decay by using visual observation and scanning electron microscopy examination.

2. EXPERIMENTAL

2.1 Glass samples

A series of 24 glass fragment of different colors and typologies was collected, fully cleaned from the soiled deposits and weathering crusts, and prepared for the chemical analysis and SEM examination. Investigations includes these glass fragments addition to the five glass objects which could not be sampled but examined visually.

2.2 Analytical techniques

The glass samples were analyzed by the means of a Philips Magix pw 2424 X-ray fluorescence spectrometer (XRF), which uses the high-purity silica BCS-CRM 313/1 standard certified reference material from the Bureau of Analyzed Samples LTD, UK and works under vacuum, voltage 20-60 KV, current 5-150 mA and a Power limit of 4050 watt. Furthermore, microscopic and optical assessment was carried out. A scanning electron microscopy (SEM) model FEI Quant 200) operated in a secondary electron mode was used to examine the surface morphology and investigate the structure of encrustations and the underlying glass surface.

3. RESULTS AND DISCUSSION

3.1 Chemical characterization

The compositions of the previously described 24 glass fragments collected from the Roman tombs no. 1 and 3 as provided by the aid of X-ray fluorescence spectroscopy (XRF) are shown in Table 1. The results of the analyses indicate that the major components of the glass samples are: silica (SiO_2 avg. 67.85%), soda (Na_2O avg. 14.98%), lime (CaO avg. 8.79%) and alumina (Al_2O_3 avg. 2.97%). They were also characterised by low contents of potash (K_2O avg. 0.76%) and magnesia (MgO avg. 0.51%).Therefore, these glasses can be classified as soda-lime-silica (Na_2O-CaO-SiO_2) glass, and correspond to the previously defined Levantine I glass group, the common type of ancient glass for more than three thousand years (Freestone, 2002, 2005, 2006; Foy et al., 2003; Tite et al., 2006; Schibille et al, 2008; Foster and Jackson, 2009; Abd-Allah, 2010).

This composition revealed that the main raw materials from which these glasses were manufactured were Levantine coastal sand as a source of silica, natron (from Wadi Natrun in Egypt) as a source of alkali soda, and lime (which is already present as impurity or shell fragments in the Levantine coastal sands) as a source of calcium (Abd-Allah, 2010). However, no evidence for a local primary production of raw glass (the preparation of fresh glass from its raw materials through fritting and melting) or a secondary production (the preparation of a quantity of hot glass by melting the primary glass in crucible, processing and finishing it into glass artefacts) at these sites has been found to date. It was stated that glass production in the first millennium AD was divided between a relatively small number of workshops that made raw glass and a large number of secondary workshops that fabricated vessels. During the Roman and later periods, glass was produced from its raw materials in massive tank furnaces in a limited number of glass production centres (potentially in the Levantine area). The unformed chunks of raw glass originating from these furnaces were then re-melted to produce glass vessels at a larger number of glass working centres (Freestone et al., 2008). According to Abd-Allah (2010) raw glass chunks were imported to secondary production centres in Northern Jordan (such as Beit Ras) for local reworking in order to produce glass vessels in large quantities.

The high content of manganese oxide in samples 1 and 2 (MnO 0.54% and 0.32 % respectively) indicate that manganese was intentionally used as colorizing agent in the form of (Mn^{3+}) ion to color the glass purple or violet. Whereas in all other transparent and colorless samples, manganese was used as decolorizing agent in the form of (Mn^{2+}) ion which acts as an oxidizing agent and converts the iron from its reduced state (Fe^{2+}, which is a strong greenish blue colorant) to an oxidized state (Fe^{3+}, which has a yellowish, but much less intense, color) (Jackson, 2005; Abd-Allah, 2009).

3.2 Visual and microscopic investigation

As shown in Figure 3, some uncovered glass objects were found intact but suffering from different deterioration phenomena, the others were found completely fragile, broken down into several fragments and great area of their bodies was missed. Both the inner and outer surfaces of the glasses completely are corroded and covered with thin, milky layers of corrosion products. Eventually these layers separate slightly and, being of different and irregular thickness, refract light differently, given a colored effect known as iridescence. The layers became extremely fragile and peel off in very thin, onion skin-like pieces.

All the glass objects were found wet and covered with thick, hard layers of salty soiling and dirt, which strongly adhered to the glass surface. Moreover, the interior if the glasses were filled with a hard lump of soiling and dirt (Figs. 4, 5). Scanning electron microscopy examination of glass samples reveals that glass was completely corroded. It was observed that deterioration proceeding from the surface to the interior. In most cases large areas of the weathering crusts are destroyed, rich in dissolution voids and losses its glassy nature. Other aspects of deterioration were observed such as formation of weathering crusts, calcareous salt growing, soiled deposits covered glass surface, cracking and pitting of corroded surface (Fig. 6).

3.3 Burial conditions assessment

Inside the rock-cut tombs numbered1 and 3(Fig.3 and 4), the mentioned glass objects were buried together with other bony, metallic and pottery remains in a damp, cohesive, salty, calcareous clay soil (Soil moisture content= 6 %; PH value= 8.4; Salinity (EC)= 3.4 m.mohs/cm^{-1}; Density=2.6 gm/cm^3 ; Porosity= 60%).Under these conditions, the glass has been broken down. Furthermore, it has been subjected to very intensive chemical deterioration; the flux is leached out preferentially to the silica, and the corrosion process is continues. It has been stated that the damp soil is most attack of glass rather than the dry one. Moreover, changes will resume as The complicated problem that emerged during excavation work is that these tombs have been in previous years subjected to acts of digging or theft in a random manner; resulting in a scattering of glass objects and artifacts pieces randomly, and were found to overlap with many other materials in a state of weakness. Corroded glass is sensitive to moisture and should be stored in as stable an environment as possible. Ideally, the relative humidity should be 40% or less (Singley, 1981; Scichilone, 1995; Abd-Allah, 2007). In a alkali- rich glass sodium and potassium are slightly soluble in some glass compositions. In the presence of high relative humidity, these components can be leached out to the surface of the glass where they are converted to carbonates. These carbonates attract moisture, and small droplets of water begin to appear on the surface of glass; hence, the name *weeping glass.* The leaching process causes tiny cracks to appear in the glass, and eventually the glass can be become opaque with small surface flaking. Further leaching and droplets formation will be stopped if the glass is kept at a relative humidity below 40%. If the storeroom is very damp, it may be necessary to pack glass in airtight container with silica gel. Furthermore, glass objects should be stored in a suitable boxes or cardboard containers. In addition to artifacts, supplementary scientific data, specimens, and samples are also in need of curatorial care. So those materials were packaged and identified separately from other artifact.

Figure 4: Buried glass objects uncovered in tomb no.3 together with other numerous finds, season 2009.

Figure 5: Glass objects after lifting from burial environment and first aid treatment.

Sn.	Form style	Color	Oxides (wt.%)													Total %
			SiO_2	Na_2O	K_2O	CaO	Al_2O_3	MgO	MnO	Fe_2O_3	PbO	TiO_2	P_2O_5	SO_3	Cl_2O	
1	Small flask	Yellowish green	67.65	15.12	0.95	8.90	2.55	0.80	0.54	0.64	0.07	0.08	0.21	0.09	0.91	98.51
2	Long- necked bottle	Yellowish green	67.09	14.80	0.87	8.78	3.46	0.49	0.32	0.48	0.09	0.11	0.16	0.13	0.77	97.55
3	Thin-walled vessel	Colorless	67.42	14.97	0.76	8.82	3.47	0.47	0.06	0.53	0.06	0.13	0.13	0.12	0.82	97.76
4	Small beaker	Greenish blue	67.36	14.69	0.71	8.93	3.02	0.51	0.03	0.52	0.06	0.07	0.11	0.13	0.96	97.10
5	Long- necked bottle	Greenish blue	67.71	15.11	0.61	8.46	2.81	0.45	0.05	0.55	0.10	0.11	0.17	0.09	0.82	97.04
6	Small beaker	Light blue	68.77	15.00	0.69	8.57	2.74	0.50	0.03	0.46	0.07	0.12	0.13	0.10	0.94	98.12
7	large bottle	Light blue	67.48	14.49	0.76	8.89	3.10	0.48	0.04	0.53	0.05	0.09	0.11	0.08	0.92	97.02
8	Small flask	Yellowish green	68.34	14.77	0.71	9.03	2.82	0.45	0.05	0.52	0.02	0.09	0.17	0.18	0.73	97.88
9	Small flask	Greenish blue	67.86	15.22	0.74	8.76	3.19	0.56	0.02	0.44	0.03	0.10	0.12	0.12	0.85	98.01
10	Long- necked bottle	Yellowish green	68.69	15.13	0.68	8.90	2.83	0.49	0.04	0.47	0.04	0.09	0.11	0.08	0.83	98.38
11	Small flask	Greenish blue	67.14	15.21	0.69	8.93	2.75	0.52	0.03	0.47	0.07	0.03	0.14	0.11	0.82	97.04
12	Small beaker	Light blue	68.95	15.54	0.64	8.34	2.67	0.54	0.02	0.53	0.04	0.09	0.11	0.15	0.94	98.35
13	Thin- walled vessel	Greenish blue	68.45	15.32	0.73	8.65	2.93	0.55	0.04	0.43	0.04	0.10	0.28	0.13	0.84	98.48
14	Small flask	Greenish blue	67.43	14.91	0.74	8.68	3.18	0.47	0.03	0.48	0.08	0.11	0.16	0.11	0.65	97.03
15	long- necked bottle	Light blue	68.44	14.56	0.92	8.79	2.82	0.45	0.05	0.52	0.02	0.09	0.17	0.18	0.73	97.74
16	Thin- walled vessel	Light blue	66.99	14.63	0.77	8.88	2.94	0.58	0.04	0.54	0.08	0.13	0.19	0.12	0.83	96.72
17	Small flask	Light blue	67.01	15.14	0.82	8.96	3.04	0.52	0.04	0.45	0.03	0.06	0.16	0.10	0.80	97.13
18	Thick- walled vessel	Yellowish green	67.29	14.98	0.89	8.94	3.09	0.61	0.03	0.56	0.05	0.10	0.12	0.09	0.71	97.46
19	Long- necked bottle	Yellowish green	67.38	15.10	0.68	9.02	3.33	0.49	0.04	0.55	0.11	0.08	0.34	0.09	0.69	97.90
20	Small beaker	Light blue	68.05	15.02	0.84	8.75	2.72	0.49	0.03	0.53	0.07	0.08	0.13	0.14	0.82	97.67
21	Small flask	Light blue	68.54	14.75	0.81	9.00	2.92	0.42	0.05	0.56	0.08	0.09	0.24	0.16	0.78	98.40
22	Small flask	Greenish blue	68.95	15.10	0.68	8.54	2.69	0.50	0.04	0.53	0.06	0.09	0.15	0.14	0.81	98.28
23	Thin- walled vessel	Greenish blue	67.42	14.97	0.76	8.82	3.47	0.47	0.06	0.53	0.06	0.13	0.13	0.12	0.82	97.76
24	Long- necked bottle	Light blue	68.07	15.08	0.80	8.85	2.75	0.43	0.06	0.57	0.09	0.12	0.16	0.12	0.81	97.91
Avg.%			67.85	14.98	0.76	8.79	2.97	0.51	0.07	0.54	0.06	0.09	0.16	0.12	0.81	97.71

Table 1: Chemical composition of the selected glass samples obtained by XRF.

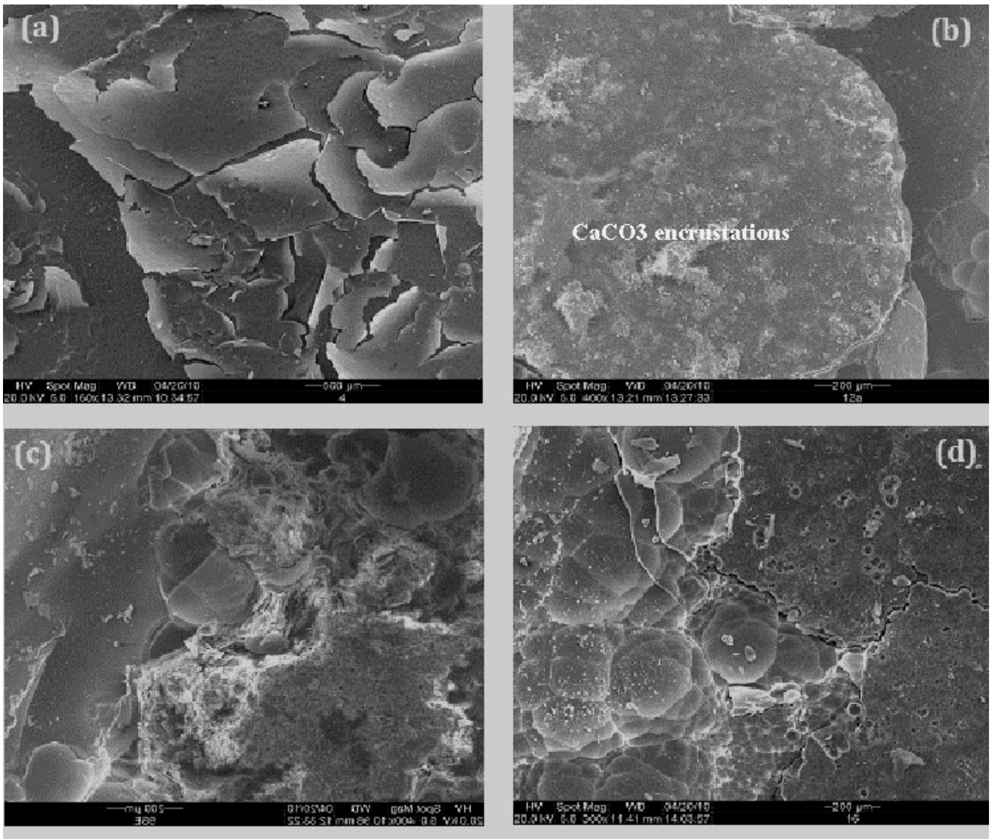

Figure 6: Secondary electron images of damaged glass samples showing the aspects of (a) formation of weathering crusts, (b) formation of calcium carbonate encrustations, (c) soiled deposits covered glass surface, (d) cracking and pitting of corroded surface, large areas of the weathering crusts be destroyed, rich in dissolution voids and losses its glassy nature.

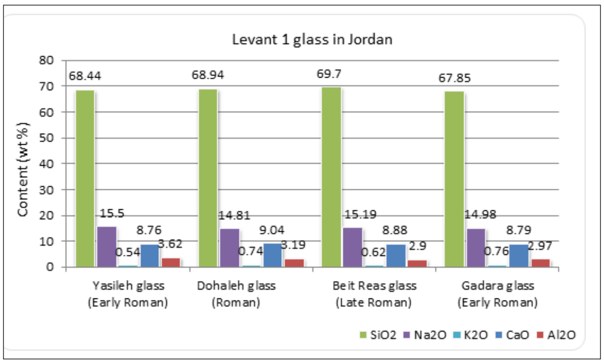

Figure 7: Levantine1 glasses from the Roman sites of Yasieleh, Dohaleeh and Beit Ras) compare with glass from Gadara in Northern Jordan. (Data of Abd-Allah 2010, 2012.

4. CONCLUSION

The results of the chemical analyses indicate that the glass does not show a clear distinction in terms of chemical composition between the Roman glass from Umm-Qais/ Gadara and the other Roman sites in Northern Jordan. The resulting data shows that the analysed samples are examples of soda-lime-silica glass, with natron used as flux, which was probably mostly obtained from Wadi Natrun in Egypt. Lime or calcium carbonate was certainly unintentionally present in the composition, due to the use of lime-rich quartz sand from the Syro-Palestinian or Levantine coasts; thus, calcium carbonate was incorporated with the sand rather than added as a separate component (Hatton et al., 2008). All the analysed glasses correspond to the previously defined Levantine I glass group (Fig. 7).

Buried glass mostly found in bad condition and subjected to intensive corrosion and other deterioration aspects such as pitting, cracking, encrustation, dulining and salt crystallization . So glass found dry should be kept dry as well. Dry pieces of glass should be packed in a rigid container which is well padded with acid-free tissue, and a layer of moisture-absorbing silica gel should be placed in the bottom of the container before putting in the padding to prevent the glass from further corrosion. Glass should be stored in as stable an environment as possible. Ideally, the relative humidity should be 40% or less.

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HISTORICAL AND MATERIAL APPROACH TO THE PAINTINGS AT THE PORTUGAL NATIONAL LIBRARY: CONTRIBUTIONS TO THE HISTORY OF CONSERVATION AND RESTORATION OF EASEL PAINTING IN THE 19th CENTURY

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KEY WORDS: Paintings, Convents, Conservation, Restoration, Nineteen century

ABSTRACT:

There are in the National Library of Portugal (BNP) about fifty paintings from former convents, mainly portraits executed between the sixteenth and nineteenth centuries, which are hung in rooms and along corridors, far from the eyes of the public and simultaneously protected by recent conservation and restoration interventions. These paintings, of little artistic interest, are, however, individual cases for the study of conservation and restoration interventions made in the nineteenth century. The data obtained will contribute to the history of paintings restoration, in terms of its practical aspects (about materials and techniques used), that is still to be written in Portugal.
Our research, which began in January 2011 and is predicted to end in December 2013, has been oriented by three complementary lines of action, with an interdisciplinary methodological base: the exploitation of the BNP's precious and unpublished documental archive; the assessment to the conservation status of the paintings and identification of restoration works; and the material study of the works, from physical and chemical methods of examination and analysis, in order to deepen our technical knowledge about the restoration of easel painting in the nineteenth century.
Through historical documents we could identify periods of restoration, restorers and materials used. The observation of paintings allowed selecting a set of twenty-seven pieces that showed old restorations, made in the nineteenth or early twentieth century. In addition it's very important to use examination methods and laboratory analysis to characterise the restoration works and the materials used.

1. INTRODUCTION

With the suppression of religious orders in Portugal, in 1834, and the subsequent nationalization of its assets, the State became responsible for a significant number of works of art, particularly religious in nature. To assist the management of the collections, several deposits were created, each one with thousands of pieces. We are particularly interested in the *Deposit of the Libraries of the Extinct Convents*, established at St. Francisco Convent, in Lisbon, in which not only a large part of the monastic libraries was directed to, but also thousands of religious paintings. The paintings that came to the *Deposit*, in general, were later dispersed among numerous public buildings, churches and museums around the country.

We intend to study the action of heritage protection exercised by the *Deposit*. The surveying and systematic analysis of the wealth of unpublished documents, has allowed for a much greater overall understanding of how the safeguarding carried out since 1834 operated. At the same time, it has also revealed essential information concerning the conservation and restoration treatment some works underwent, showing the materials and techniques used, and by which artists.

In addition, a material study of the National Library's paintings will be undertaken, particularly those that appear to have been little intervention during the 20th century, with a view to understand the restoration works carried out in the 19th century and to determinate the consequences of the process that began with the entrance of the paintings into the *Deposit*. This material study will be carried out by the laboratory study of the works. It's essential to confront and complement the results coming from physical and chemical methods of examination and analysis with the information obtained through documental research, in order to compare theory with practice.

This study, based on both analytical and documental components, raises relevance that goes beyond the works of the Portuguese National Library. The documentation, which is exceptionally rich in information on the issues of protection and wealth management, contribute to the knowledge of the history of painting restoration in Portugal over a period about which very little is known. At the same time, it contributes to the same theme in terms of European knowledge.

2. THE SET OF PAINTINGS

The set consists mostly of portraits of religious figures or figures of the Portuguese court. There are also battle scenes and mythological representations alluding to Aeneas and the Trojan War.

Why are there religious paintings of the XVI-XIX centuries in a library built in the 1960's? This was a main issue and a focus point to develop this study.

Simultaneously, some of these old paintings seem to be relatively untouched by recent restoration works, which presents a rare opportunity to characterize the 19th and early 20th century restoration processes, often aggressive, that not only significantly changed the visible image of the work, as it had an impact on the degradation processes that occurred normally.

A study of this nature is harder to do with works displayed in museums, subject to regular operations, maintenance and renovation that will erase the marks of earlier interventions. Thus, this study will contribute decisively to the knowledge of the history of conservation and restoration of paintings in Portugal during the 19th and early 20th century, by the articulation of the historic and documentary survey with the laboratory studies.

The paintings have had little interest among art historians due to its low artistic quality. However, provide a rare opportunity to study the criteria and materials used in old restoration works.

3. THE KNOWLEDGE PROVIDED BY THE HISTORICAL ARCHIVES

The archive documents and some testimonies published at the time are essential sources for correct historical research into the theory and techniques used in conservation and restoration works. These documents have provided new and important information to the understanding of the value of National Library's pictorial heritage in the nineteenth century, as well as the conservation problems that the paintings have or had.

3.1 Convent of San Francisco: conditions of the space where the paintings were

The choice of the convent of San Francisco as a deposit of the spoils of the religious houses was due to its central location and the strength of its construction, revealing, therefore, that this building seemed suitable for this purpose.

But the old Franciscan convent immediately showed that it was unsuitable for the intended new functions. The infiltration of rainwater appears to have been the biggest problem, presenting itself as a real risk to the collections deposited in the building.
The water and moisture, dust, moths and poor ventilation were the main problems of the building.

3.2 Conservation state of the paintings

The poor condition of the paintings seems to have been a reality. Several witnesses in the nineteenth century talk about it.
Many paintings remained rolled, folded and stacked.

The weaknesses of the building and the bad storage conditions caused many paintings to be considered lost in 1844. Even in this state, José Feliciano de Castilho de Barreto e Noronha (1810-1879) considered that all works should be saved, but this was not the understanding of those who followed him in the direction of the National Library. Therefore, in 1853, a significant number of paintings were burned, since many were in ruins or consisted only of rags.

In the late 1890s, Gabriel Pereira, then director of the National Library, said that he had found the pictures, almost all poorly maintained.
Several actions were responsible for reducing drastically the number of paintings that were in the National Library. Currently, there are a little more than fifty paintings from the extinct convents.

3.3 Restoration works carried out in the nineteenth century

The history of conservation and restoration of painting is not done in Portugal. Internationally, studies are fragmentary and are directed mainly to the great masters.
In the paintings of the National Library of Portugal, through archival documentation, we were able to identify three moments in which the paintings of the deposit of San Francisco were intervened with.

We noted restoration works in 1835, in 1864 and in 1888. The first was made by the painter André Monteiro da Cruz (1770-1851), the second by João António Gomes and António da Costa e Oliveira and the third by the painter Luciano Martins Freire (1864-1934). If Luciano Freire is a well-known artist, this is not the case with others. Those are names that have been little studied in the field of painting as in the field of restoration. The documentation is not always rich, both for work performed and the materials used.

In 1835, we know that the most treasurable works, made by the sixteenth-century Portuguese painter Grão Vasco, were "repaired"; the necessary stretchers for paintings on canvas were made; and some works were cleaned and "prepared".

We note a great concern with a few works, considered masterpieces. There isn't the same concern with all the works. Until this moment, based on the documentation, we knew little about materials and techniques used in the restoration for this phase.

In relation to the restoration of 1864, we have information that about seventy portraits were restored (Figure 1). Its "cleanup and restoration" was made, and of their respective frames, and numerous materials in the old drugstore F.J.Carvalho (Lisbon) were acquired.

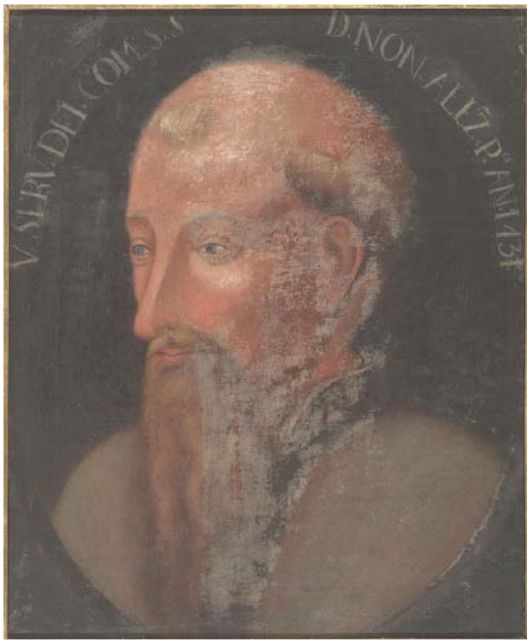

Figure 1: Unknown Author, Portrait of Frei Nuno de Santa Maria, seventeenth century (?), oil on canvas, 42.5 x 35.5 cm, National Library. Painting restored in 1864.

The following materials were purchased, and among them various pigments:

Dark green	English oil
Dragon's blood	Turpentine
English blue	Ceruse in powder form
Shadow of Cologne	Alcohol 40 º
Painter's gypsum	Shellac
Black of Italy	Fine potash
Ochre	Spirit varnish
Anise flower	Chalk
Reddle	Powdered faeces
Ultramarine blue	Black ("powder of shoes")
Peruvian green	Zumatic

Table 1. Materials for the restoration of 1864.

This information, rarely provided by documentation, is extremely important for comparison with laboratory results, whose studies we expect to start next September. The data will help us to identify and characterize the old restoration works, and to date them. It's also essential to establish a relationship with the pigments used in Europe at the time, in order to retrieve more conclusions. The same applies to the restoration works of 1888. At that time, the famous painter-restorer Luciano Freire was commissioned to refresh and fix the inks that were used in many paintings of the National Library.

Luciano Freire did cleaning, retouching, varnishing and replacement of stretchers on a large number of works. Twenty-nine works restored by him were identified (Figures 2 and 3).

Figure 2: Diogo Pereira (attributed), Fire of Troy, 1600-1650(?) oil on copper, 35,5x86,5cm., National Library. Painting restored by Luciano Freire in 1888.

We found also some lists of materials acquired for restoration. In these lists, which consist in receipts of purchases, we find:

Milled ceruse	English green
Turpentine	Imperial green
Linseed oil	Reddle
Chalk	Black ("powder of shoes")
French secant	Ultramarine blue
Powdered faeces	Peruvian green
Bitumen	Light English green
Glue from Oporto	Vermilion
Zumatic	Dark green
Sorrel salt	Painter's gypsum
Plaster	Flatting varnish
Alcohol 40 º	Crystal varnish

Table 2. Materials for the restoration of 1888.

Figure 3: Carlos António Leoni, Portrait of Fray Miguel Contreiras, 1766, oil on canvas, 187,5x125cm, National Library. Painting restored in 1864 and in 1888.

4. EVALUATING THE CONSERVATION OF TWENTY-SEVEN PAINTINGS

4.1 Selection criteria

After a careful observation of the set of monastic paintings, the conservator-restorer, who belongs to the research team, selected twenty-seven paintings. According to her, the others appear to have been restored more recently.

The observation was performed without optical observation equipment and without the execution of any method of examination and analysis. This is a pre-selection, which can be changed after use of laboratory resources.

4.2 Assessment of the state of conservation of paintings

The twenty-seven paintings observed received the following interventions:

Interventions	**Paintings**
Cleaning, varnishing and touches	27
Occasional inpaintings	11
Fills surface	21
Inscriptions	3
Coloured masses	2
Patches	3
Linings	2 or 24
Cutting strips of canvas	2
Collage with synthetic adhesive	1
Stretchers	2 or 20
Application of tacks	1

Table 3. Interventions identified in the 27 observed works.

Cleaning, varnishing and touches are observed on all the selected paintings. This is visible by the absence of dirty aggregates, bright and thick varnish and by the colour change of retouching.

Occasionally, clearly visible in eleven works, the paintings show a different texture, a matte appearance and sometimes direct application on the support (without preparation). Filled surfaces are identifiable when compared to the original, mainly by the difference in texture.

There are three inscriptions in three paintings: a caption on the pictorial layer, another on a patch and a third on a paper glued on the stretcher.

In the reverse of two works, there was a thick layer of light brown paste on the support (which is not yet determined if it is original or not) and another thin and dark brown layer.
Cut strips of canvas are visible on two paintings, which don't have the surface layers of paint and textile backing in the peripheral areas.

Three paintings presented patches of different types (coarse cloth, cardboard, tape).

It is safe to say that the lining was done in two of the paintings.
Although the observation at the back of the paintings have been difficult and limited, the appearance of the surface and the stiffness of the backing, leads us to suppose that there's more linings in 22 paintings, many of them executed with industrial textiles and wax-resin.

There is too a collage with synthetic adhesive, just in one painting on board.

For the same limitation that was indicated above, for now it is only possible to ensure that two stretchers are not original, because they don't have the corresponding dimensions of the paintings, but it seems that other 18 also result from restoration, by its appearance and by visible marks on the surface.
Many of the twenty-seven observed works have similar interventions, both from a technical standpoint, and in terms of materials used.

After analyzing the first data collected in the twenty-seven paintings, we considered that a further study in three works should be done: portraits of *D. Afonso Henriques*, of *Friar John of Our Lady* and *Gentleman in the red hat* (Figures 4, 5 and 6).
This selection focused in these works because they present multiple and distinct old restorations, from different dates. However, most of the data needs to be confirmed by examinations methods and laboratory analysis.

4.3 Intervention criteria followed

The conservation criteria was fully established over recent decades, involving respect for the works of art and the selection and justification of the procedures adopted in terms of materials and techniques, and implying as little invasive action as possible, were essentially non-existent before the 2nd half of the 19th century (Cruz, 2007). Up until then, restoration work had involved general repainting, frequent stylistic and iconographic modifications, treatments using procedures and materials that were often kept as guarded secrets out of jealousy, but there are some references in a number of technical or, in particular, encyclopaedic works which confirmed that these were extremely aggressive. On one hand, the cleaning of easel paintings consisted in using brushes and sponges; and, on the other, it could employ the use of bleach, turpentine, whitewash or hot water, among other substances (Rodrigues, 2007; Serrão, 2006). It is possible that the procedures and materials used were similar to those in other countries.

Figure 4: Unknown Author, Portrait of D. Afonso Henriques, the first king of Portugal, seventeenth century (?),oil on canvas, 224x133 cm., National Library.

Regarding the paintings from the National Library, we demonstrated that many restorations were usually identified as intending the "aesthetic" effect only. We find in all of them pictorial surface cleaning, varnishing, retouching and inpaintings.

About inpaintings (occasional or generalized), there are often differences in the same work. Sometimes the application of colour is made directly on the support, sometimes on a preparation, exceeding the limits of the lacunae in an invasive approach. This attitude gives us the indication that these interventions were not implemented with the principle of the maximum respect for the original work.

In most inpaintings, it is clear that a colour selection criteria was followed, although today the colour has changed. Therefore, it is unclear if the colour changed due to the natural aging process or due to poor technical mastery by the restorer.

Overall, the intervention criteria followed does not correspond to the present criteria, especially the respect for original materials and the use of reversible and compatible materials that do not affect the original work.

Figure 5: Portrait of D. Afonso Henriques. Detail of repaints on armor.

Thus, most of the work performed (varnishing, repainting, linings), exceeded what was necessary for the conservation of the paintings, moving away from what we understand today as minimal intervention.

Also, there is not an absolute respect for the original work, or the care to differentiate the techniques and materials used in the restoration work. Thus, most touches are performed with oil ink, mimicking the original lost areas. They are also sometimes large, concealed parts of the original surface.

Figure 6: Portrait of D. Afonso Henriques. Detail of touches in the shield.

It is not possible to determine exactly the materials used in restorations at this point. However, it's clear that some materials, such as those used in the inpaintings and the adhesives of the linings are not reversible, because, according to what it is possible to observe, the first case ink oil was used, and in the second wax-resin.

As from the late 18th century, concerns about restoration work began to be voiced (Pietro Edwards, in Italy; the National Gallery, in England) (Bomford & Leonard, 2004; Conti, 2002; Macarrón Miguel, 1997; Ruiz-Mateus, 1994), but such worries seem to have had little impact on restoration in Portugal, at least until the late 19th century (Cruz, 2007). In this period, some of the most illustrious Portuguese restorers, such as Manuel Macedo and, later, Luciano Freire, established some limits and criteria for restoration works, with the former writing, in 1885, that "there are cases in which restoration damages" (Cruz, 2007).

5. LABORATORY SUPPORT

The material study, which is the third and final phase of the project and that will begin, as we said, in next September, will be carried out by a laboratory study of the works. Instead of the usual material characterization of the original paintings, as usual, this laboratory work on some of the paintings will consist of the detailed reconstitution of the restoration work carried: reconstructing the procedures followed, the materials used and the underlying restoration principles.

It will be essential to confront and complement the results coming from physical and chemical methods of examination and analysis with the information obtained through documental research.

Therefore, the aim is to study the restoration of the selected paintings with a view to answering questions such as the following:

- What kind of restoration work was carried out?
- How was it carried out?
- What was the scale of the restoration work?
- How were restoration materials used in relation to original materials?
- What materials were used in the restoration work?
- To what extent can the original materials be recognized?
- From the material point of view, was the restoration work justified in terms of how it was carried out?
- How did the restoration materials develop?
- What consequences could the restoration works have had as regards the conservation of the works?
- To what extent has the restoration work affected the current image?

To answer all these questions we shall mainly use examination methods and laboratory analysis to characterize the restoration work and the materials used. Laboratory studies of paintings usually focus as much as possible on the original materials of the paintings and not as significantly in the conservation and restoration work. Here, however, the examinations and analysis will focus principally on the restored areas.

Radiographs and technical photographs are a major part of this process. By its special nature, they can only be done with the support of the technicians of the photographic and radiographic laboratories at Polytechnic Institute of Tomar.

Therefore, it will be possible to characterize and understand the effects of this restoration work in detail, mainly in terms of image. Although our results will be based on a specific group of works, the information pertains to the material history of most paintings, which is usually difficult to obtain, but will hopefully be of general use.

We will then move on to identifying the materials used in the former restoration work through chemical analysis. Pigments, loads and binders will be determined. Whenever possible, non-invasive methods will be used, such as the spectrometry of x-ray fluorescence for pigment identification, at the BNP itself.

However, due to the limitations of these methods, we will need to use samples taken from the paintings. When relevant, similar analysis will be done on the original material. The materials identified in the restored areas will be compared to the archive documentation and the technical literature of the era. Due to its importance for our study, we hope to be able to present some results of laboratory experiments at the Congress poster presentation.

Assessing the works' state of conservation will enable us to learn about the problems displayed, the risk of loss as well as leading to proposals to ensure the safeguarding presented by the BNP paintings.

6. FINAL REMARKS

The great importance and originality of this project, with its interdisciplinary methodological base, stems from two decisive factors: the existence of innumerable unpublished historical documents; and the rare opportunity to study old restorations, since the most recent restorations tend to "erase" the previous ones.

The data obtained is important in the history of art, and might be crucial for the conservation and restoration. The materials used above may influence the choice of products to be used in future restoration interventions, particularly in respect of consolidates or solvents used in cleaning (Cruz, 2000).

With the data obtained, we will contribute to the knowledge of the history of conservation and restoration of paintings in the nineteenth century, both in Portugal and in Europe.

Bearing in mind that bringing such studies to the attention of various sectors of the public is increasingly a guarantee of heritage sustainability, in parallel with academic studies aimed at a more specialized group, the challenge is to find other forms of spreading this new information, which will create greater interest and curiosity in a wider-ranging public, uniting enjoyment and knowledge. To this end, there are plans to create a dissemination program based on modern technology (Internet page and electronic voice and image kiosk), in order to deliver this information to an audience as wide as possible.

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Colonization of Maltese Catacombs by Phototrophic Biofilms. How Much Does Light Matter?

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KEY WORDS: cyanobacteria, diatoms, green algae, red algae, distribution, species richness

ABSTRACT:

The study of phototrophic biofilms from Maltese catacombs has shown that their distribution within catacombs does not show a significant dependence on orientation of catacomb and their location inside the catacombs. A decrease on species richness is observed when light availability diminishes, but the composition of biofilms does not change significantly. The proportion of green algae has a slight increase in darker areas, while cyanobacteria remain stable and diatoms decrease. Diatoms are almost not present in deeper areas inside catacombs. However, light is not the only key factor driving the colonization by phototrophic biofilms.

1. INTRODUCTION

Hypogeal structures, either natural or man-made, encompass very peculiar environments with steady conditions in terms of temperature and humidity, but with restrains in nutritional aspects; consequently, they host specific communities which are well adapted to such conditions. Among those communities, phototrophic biofilms are affected not only by temperature and water availability, but also by light conditions.

Phototrophic organisms forming biofilms are able to colonize hypogeal sites where light is available, mainly entrances and nearby areas (Hernández-Mariné et al., 1999; Roldán et al., 2004; Albertano et al., 2005). Their extension inside hypogea depends on light extinction, which varies daily and seasonally. Furthermore, colonization of stone surfaces is thrived by substrate bioreceptivity (Guillitte, 1995; Warscheid & Braams, 2000). Once a community is established it has to deal with the limiting conditions generated in subterranean sites (Ortega-Calvo et al., 1995).

New aspects arise when natural or man-made hypogea are conditioned by making them accessible to visitors. Installation of artificial light together with the presence of visitors modifies the original conditions further promoting the colonization of phototrophic biofilms. These organisms compete with preexisting heterotrophic and lithotrophic communities (Sanchez-Moral et al., 2005), thereby altering the equilibrium between preexistent organisms and substrate resulting in an increase in biodeterioration. In addition, we do not expect to have the same composition of phototrophic biofilms colonizing new areas at a greater depth within the sites, compared with the established communities at the entrance or nearby. The main difference lies on light irradiated from bulbs or any artificial source which is different from sun radiation. Therefore, we expect changes in specific composition as well as in abundance of species between communities thriving on natural light or on artificial light (Mulec et al., 2008).
Previous studies on Maltese hypogea have provided data from the diversity on biofilms (Zammitt et al., 2011a) and how they affect artworks present on those sites (Zammitt et al., 2011b). We have focused on the catacombs of St Paul and St Agatha, located in Rabat. The two catacombs areas were opened to visitors in the middle of 20th century, while the remnants catacombs remained closed and only occasionally visited for research purposes. The possibility to study all the catacombs has allowed us to compare the colonization by biofilms on areas with natural light from areas with artificial light.

The aim of our study was to check phototrophic biofilms from all the areas that looked colonized and compare if there were some differences in the composition of biofilms growing on artificial and natural light.

2. MATERIAL AND METHODS

The site consists of two large areas normally called St Paul's and SS Paul/Agatha, consisting of more than 30 hypogea. The main complex, situated within the St Paul's cluster, comprises a complex system of interconnected passages and tombs of an area of well over 2.000 sq,m. While catacombs at St Paul's area have been visited since the middle of 20th century; the catacombs in SS Paul/Agatha area have not been visited, except for research purposes.

For each catacomb several sampling points have been selected, extending from the entrance to the deepest part reached by natural light and where colonization was observed. We tried to measure PAR for sample but the punctual measures do not compile the variation experimented through the day and the year. Therefore, we have categorized the environmental data

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related to light according to the distance from the entrance into three different levels: entrance, inner hall and dark areas (where only artificial light was the light source). We have also considered the orientation of catacomb entrances, as will affect the light coming inside during the day and along the year. Apart from the points inside Catacombs in St Paul's area, labeled as artificially illuminated, the orientation has been referred to as north, east, south and west.

The identification of components of phototrophic biofilms was carried after sampling minute portions of substrate and culturing the samples. Cyanobacteria were cultured in BG11 culture medium, which is a successfully medium, used for most cyanobacteria. Green algae were cultured in a Bold's basal medium (BBM), a highly enriched medium.

Samples were examined using light and confocal laser scanning microscope (CLSM). The samples in light microscope were visualized using an Axioplan microscope equipped with an MRc5 AxioCam photomicrographic system. Cell measurements were made based on the optical images from field and cultured material. Characteristics previously considered as taxonomically important at generic and specific levels were considered. Samples from CLSM were observed in vivo. Images were captured with a Leica TCS-SP5 CLSM using Plan-Apochromatic 63x (NA 1.4, oil) objectives with different zoom ranges.

Data were processed statistically for differences of the diversity based on main taxonomic groups (cyanobacteria, diatoms, green algae and red algae) and total species richness present in phototrophic biofilms between light source, orientation of the entrance of catacombs and the location of sample inside reach catacomb. Data was found to fulfill requirements normality and homogeneity of variance for cyanobacteria, diatoms, green algae and total species richness, therefore red algae were not included in the analyses. A one-way analyses of variance (ANOVA) was performed for orientation and level to check for differences between the diversity variables considered. A t-test was run for light source to check for differences between diversity. Pairwise comparisons using t-test were applied between the categories of orientation and level once ANOVA yield significant differences. All the analyses were run as implemented in Statistica 7.

3. RESULTS

3.1 Diversity of Phototrophic Biofilms

The study of samples from the catacombs located in St Paul and St Paul and St Agatha has yield a preliminary list of 46 taxa, 21 of them have been identified only to genus level. Among the observed taxa, 27 belong to Cyanobacteria, 12 to green algae (Chlorophyta), 5 to diatoms (Bacillariophyta), and 2 to red algae (Rodophyta). Occasionally, there were protonemata of mosses and one lichen species that have not been included in the posterior comparisons.

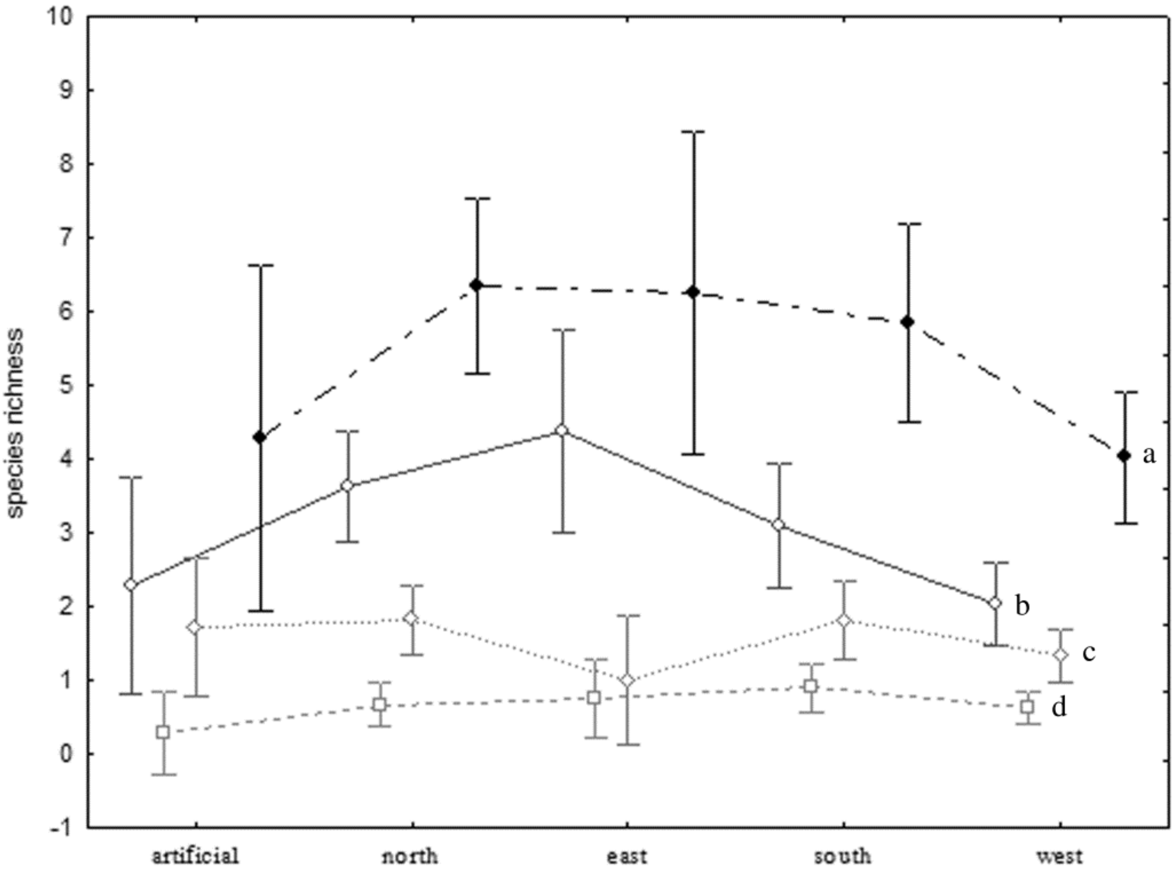

Figure 1. Distribution of total species richness (a) and species richness of components of phototrophic biofilms: cyanobacteria (b), green algae (c) and diatoms (d), from Maltese Catacombs depending on the orientation of catacomb, based on least squares means of ANOVA analyses. The central point corresponds to the mean and vertical bars denote the 95% confidence intervals.

The predominant taxa at catacombs were *Chroococcidiopsis* spp (Cyanobacteria), *Desmococcus olivaceus* (Chlorophyta)¸ *Leptolyngbya nostocorum* (Cyanobacteria), *Diadesmis contenta* (Bacillariophyta), and *Muriella* sp (Chlorophyta), which were present in more of the 30% of the samples. Three taxa related with our observations were previously recorded as predominant from several points from the main catacomb system at St Paul (Zammitt et al., 2011a).

3.2 Comparison between Parameters Driving the Colonization of Catacombs by Phototrophic Biofilms

The comparison of the effect of light on the composition of biofilms shows some differences between these samples growing in natural light from those growing in artificial light. However, the t-test analysis does not show any significant difference. Natural light enhances a richer community than artificial light. The different sampling effort does not provide enough data to have a complete look on colonization in areas with artificial light. The differences in light availability are not so significant between natural and artificial light to determine a shift in composition of biofilms. The cyanobacteria and green algae that predominate in these biofilms are able to colonize points with very low radiation (Albertano & Bruno, 2003).

The orientation of catacomb and the location of biofilms inside the catacomb have low effect on the diversity of phototrophic biofilms. ANOVA analyses were not significant for both parameters. Catacomb orientation has a slight effect on cyanobacteria. Pairwise comparisons, applying t-test, between the richness of cyanobacteria between the bearings yields a significant difference. Samples taken from the west facing points within catacombs harbor a lower species richness of cyanobacteria than samples taken from any other bearing. This difference is greater when compared with samples from east facing catacombs (Figure 1). Green algae richness does not change so markedly, except for a slight decline on the east facing catacombs, despite it is not significant. Diatoms have no clear changes on their richness depending on the orientation of catacombs. The west orientation of catacombs is affected by other parameters other than light which determine the shifts on species richness of cyanobacteria. This specific bearing would modify the availability of liquid water, a key factor for the growth of cyanobacteria. Nonetheless, the lack of long-term monitoring of environmental parameters in these hypogea does not allow hypothesizing on which particular variables are driving biofilm colonization.

The species richness diversity declines when moving inside catacombs, but those changes do not have a statistically significant difference (Figure 2). In terms of the composition of biofilms, the colonization of inner areas of catacombs increases the importance of green algae, and reduces the presence of diatoms, while cyanobacteria are not affected (Figure 3). Otherwise, the reduction of available light limits the colonization of phototrophic biofilms, but the capability of cyanobacteria and green algae to make use of very low dose of visible radiation enhances their presence even in almost dark areas (Mulec et al., 2008; Albertano & Bruno, 2003).

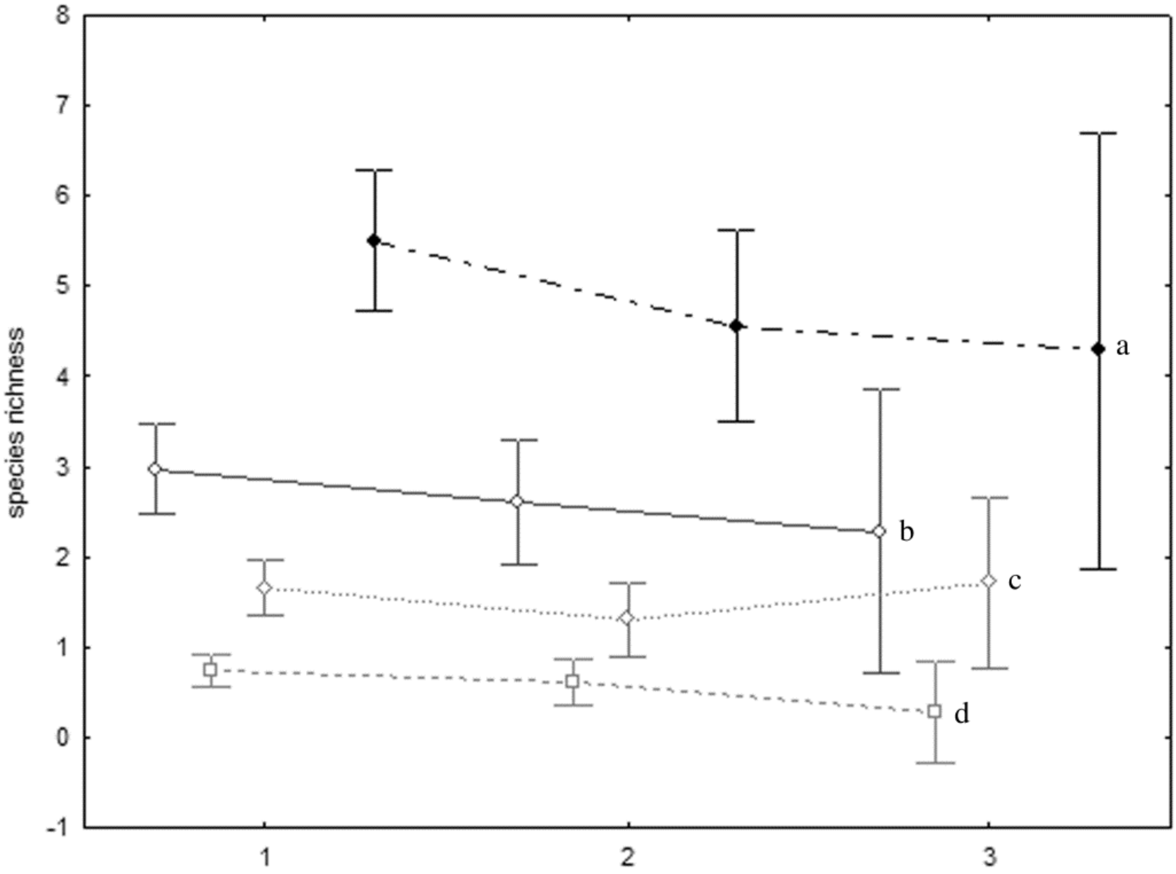

Figure 2**.** Distribution of total species richness (a) and species richness of components of phototrophic biofilms: cyanobacteria (b), green algae (c) and diatoms (d), from Maltese Catacombs depending on the location inside the catacomb, based on least squares means of ANOVA analyses. The central point corresponds to the mean and vertical bars denote the 95% confidence intervals. Location inside catacombs refers to entrance (1), inner hall (2) and dark areas (3).

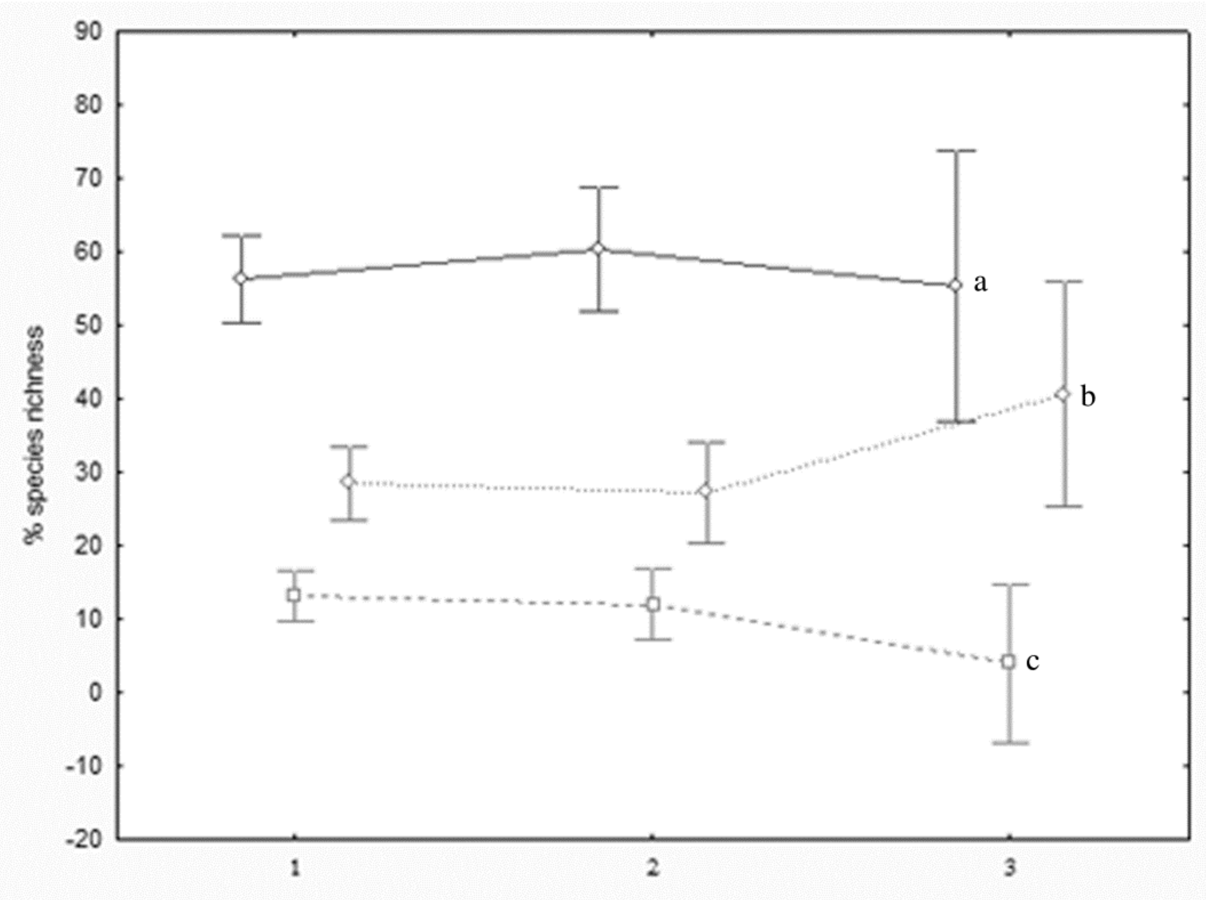

Figure 3**.** Distribution of the percentage of species richness for the main components of phototrophic biofilms: cyanobacteria (a), green algae (b) and diatoms (c), from Maltese Catacombs depending on the location inside the catacomb, based on least squares means of ANOVA analyses. The central point corresponds to the mean and vertical bars denote the 95% confidence intervals. Location inside catacombs refers to entrance (1), inner hall (2) and dark areas (3).

4. CONCLUSIONS

The distribution of phototrophic biofilms does not have a clear pattern derived from light availability; despite the fact that our data suggest that an increase in light intensity hinders the specific richness of cyanobacteria, as seen on south and west facing catacombs (Figure 1). Cyanobacteria prefer lower radiation than other phototrophic taxa, and they are better adapted to develop on such environments, due to their pigments (Albertano et al, 2005). An important point to keep in mind by curators taking care of these hypogea is that a pool of colonizing species is present which require small amounts of light to develop (Albertano &, Bruno, 2003). Therefore, increasing visitors' accessibility within the catacombs by installing any source of artificial light would enhance an increase in surface biofilm colonization. In addition, some of the more common taxa are involved in mineral precipitation and other mineralization processes (Ariño et al., 1997; Albertano & Urzi, 1999), which would promote biodeterioration of catacombs (Zammitt et al 2011a).

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JORDAN CONSERVATION of CULTURAL HERITAGE in ERA

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KEY WORDS: Cultural Heritage, Nanotechnology, Conservation, Capacity Building, Colloid Chemistry, HMCSR, UJ, Material Science

ABSTRACT:

The Jordan Conservation of Cultural Heritage in ERA – JOCHERA project is aiming at overall reinforcement of University of Jordan (UJ), Hamdi Mango Center for Scientific Research (HMCSR) in Jordan cooperation capacities for cultural heritage protection research in the context of the European Research Area and development to the Conservation centre of excellence to respond to Jordan's socio-economic needs. The JOCHERA impact will be increased capacities of the UJ in terms of (i) better research and innovation management, (ii) improved international Science & Technology cooperation and participation in FP7, (iii) enhanced cultural heritage protection research capacities, and (v) defined strategic development framework in order to increase UJ visibility and scope. Likewise, JOCHERA will increase research and innovation linkages within Jordan in particular with SMEs, enable better opportunities to young researchers and enhance EU-JO RTD cooperation landscape. The project duration is 24 months, started in 1st December 2011 and will end in 31 November 2013.

1. PROJECT CONSORTIUM

The JOCHERA consortium brings together one Jordanian and four EU organizations representing a well-defined mix of expertise for strategic development, innovation management and technological foresight.

1.1 The University of Jordan (UJ), Jordan

UJ is both a modern as well as old institution of Higher Education in Jordan. It was established in 1962. From an international perspective, the University offers 63 international programs at the undergraduate level, and 130 international programs at the graduate level and in all fields of specializations.
There are some research centres within the University; Hamdi Mango Centre for Scientific Research (HMCSR), Geo-Material Research Project centre, Water & Environmental Research and Study Centre, Marine Science Station (MSS).
UJ signed a memo of understanding for setting up and operating an information focal point to participate in EU project with the name of SRTD: "*Support Research and Technology Development and Innovation and Strategies in Jordan"* which was a project funded from EU. The university appointed Liaison *Officer* for the SRTD where the main object of this project was to promote the FP7 to Jordanian researchers inside the university, as a result the number of people involved in FP7 projects increased, two of them were granted till now: L Te-health & EMAP (2010), also two under negotiations, while there are at least 4 other projects under evaluations (2011 &2012).
UJ also was involved in many international projects included European projects such as; PTIMA, DIMAS, MELIA, MED-COLOUR-TECH - Investigation, revival and optimization of traditional Mediterranean coloring technology for the conservation of the culture heritage - and SMART.
Inside the UJ there is an agriculture incubator which has produced some spin off companies such as Bee Way (*Non Traditional Bee Products, To produce royal jelly, bee venom and bee queens)*, Timeless *(Multi Cosmeceuticals, Beauty without side effects)* , Rosy City (*Production of novelty cheese products , Tofu Cheese and Soy Milk products*, Bumble Bee *(Pollination services under green houses in Jordan)*, Amazon **(***Production of Enviro-plants, Environmental nursery)*, Specialty Meals and Diet Center *(Health food product for special need people)*

Hamdi Mango Centre for Scientific Research (HMCSR): HMCSR is an independent research centre unit established in 1999 inside UJ. The centre hopes to channel material and financial support for researchers dealing with scientific and technical problems of great importance and having impact into the Jordanian society. HMCSR is dedicated to the support of interdisciplinary as well as well-defined research projects in the fields of *Applied Science and Technology*. The centre unites scientists from various fields under one roof: e.g. physicists, chemists, biologists and engineers. HMCSR aspires to active participation in developing resources, at the University of Jordan, to conduct original research in the fields of material science, nanotechnology, biotechnology, pharmaceutical solution and drug discovery.
The main research areas are focused in nanoscience in variety of fields such as; materials chemistry, nanosynthesis, composite materials, nanostructured materials, environmental, targeted drug-delivery systems for cancer treatment, preparation of new materials for slow release of drugs from natural resources.
Some of the current research topics that are investigated inside the center: surfactant enhanced remediation of polluted water,

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targeted-delivery of macromolecular drugs for cancer cells, use of kaolinite for the synthesis of zeolites and anti-microbial zeolites, the effect of nano-sized starting powders on the physico-chemical properties of the RE123 superconducting ceramics, toxicity of Jordanian zeolitic nano tuff to the nematode, characterization and beneficiation of new-explored Jordanian zeolitic tuff from selected localities in northern, central, and southern Jordan, and investigation their capability for removal of pollutants from water. The research inside the center is coordinated within the Material Science and Nanotechnology, Biotechnology, Drug Discovery Pharmaceutical Solution laboratories.

The Material Science and Nanotechnology laboratories are divided into three **R**esearch **G**roups (RG): (I) The RG of Superconductors materials; where its goal is to produce superconductors from nano sized precursor via coprecipitation method (II) The RG of Colloid and surface chemistry; where its goals are to study colloidal solutions stability, and to use the phase science in a variety of problems (III) The RG of Natural geomaterials for construction and industrial applications, its goals are to investigate the Jordanian zeolitic tuff , the mineralogical, chemical characterization and the adsorption capability towards organic and inorganic pollutants.

Recently a Technology Transfer Office (TTO) was established inside the center to help researchers connecting their research into the applied zone in addition for helping in IP issues.

1.2 Politecnico di Torino (POLITO), Italy

POLITO represents a leading public university, in Italy and in Europe, in technical-scientific teaching and research. Founded 150 years ago, nowadays Politecnico di Torino has three Schools of Engineering, two Schools of Architecture, a School of Economics and Management, plus a Post-Graduate School. Research activities are organized in the 18 “Dipartimenti” and in 12 service centres. Furthermore, the “Dipartimenti” provide Faculties and the Schools with teaching staff.

The Politecnico is a research university interested in the balanced development of both theoretical and applied research. It has closed relationships with international institutions, companies, local government and other types of association and takes social and economic consideration into account. With more than 150 bilateral international agreements and 40 double degree agreements, POLITO has links with the most prestigious Universities in Europe. POLITO is part of some of the major European interuniversity networks, such as CESAER, CLUSTER, E.C.I.U, EUA, CMU. The participation to many international projects allows PT to count on a great experience both in project scientific and administrative management. With its involvement in 88 projects funded under FP5 and 87 projects funded under FP6, Politecnico di Torino has a strong experience in project coordination.

POLITO will participate to JOCHERA through researchers belonging to the Department of Electronics (DELEN) and the Department of Materials Science and Chemical Engineering (DISMIC). DELEN is composed of over 100 researchers in the fields of electronics, metrology and chemical measurements, wireless networks, optoelectronics, portable instruments for conservation of cultural heritage and innovative sensors for environmental monitoring, with the PhotonLab, which is an innovative laboratory for the research on high performance optical networks, components and communication systems. DELEN is involved in several national and international projects on ICT, electronics, laser technology, sensors, as High Power Laser in NANO-structured fibers, Converging Technologies 2007. DISMIC, promotes and co-ordinates teaching and fundamental and applied research activities in the following areas: materials science and technology, conservation of cultural heritage, corrosion and protections of metals, thin films deposition and plasma treatments, electrochemistry and LCA analysis. DISMIC researches are involved in several national and international projects with particular attention to the cooperation with South Mediterranean Countries: European Project Growth, FPV, NANOMAG (Development of Innovative Nanocomposites Coating for Magnesium Castings Protection 2002-2005), European Project, FP VI, MATECO (New coatings deposited by PACVD for corrosion protection 2004-2007); European Project INCO-MED, FPV, EFESTUS (Tailored strategies for the conservation and restoration of archaeological value Cu-based artefacts from Mediterranean Countries, 2003-2005), European INCO-MED Project, FPVI, PROMET (Developing new analytical techniques and materials for monitoring and protecting metal artefacts and monuments from the Mediterranean country, 2004-2007); European project SSA, FPVI, MEDAL (Mediterranean conservation alliance - 2007-2009).

DISMIC and DELEN researchers are also involved in two *ERA-WIDE projects* ((FP7-INCO-2010-6, ERAWIDE, Area INCO.2010-6.2): CB-WR-MED (Capacity building for Direct Water Reuse in the Mediterranean Area – 2010-2012) and PERA (Palestine for European Research Area – 2011-2013).

1.3 Middle East Technical University (METU), Turkey

METU is a state university, founded in 1956, currently has about 23,000 students of which 4,500 are in masters and 2,700 are in doctorate programs. METU hosts over 1,500 international students from nearly 80 different countries. METU has 40 undergraduate programs within 5 faculties. Additionally, there are 5 Graduate Schools with 97 masters and 62 doctorate programs and a "School of Foreign Languages" which includes the English Preparatory Department. The language of instruction is English. METU has **168** Erasmus agreements and **182** bilateral exchange and cooperation agreements with universities in third countries.

1.4 Fundacion Technical Research & Innovation (TECNALIA), Spain

TECNALIA is the leading private research and technology entity in Spain and the 5th largest in Europe; with 1,437 staff (164 PhDs), 121M turnover, 53 patents, 3800 clients and 8 spin-offs (2009 data). TECNALIA is very active in the FP7 with 150 projects funded (31 as coordinator). From 1st Jan. 2011, TECNALIA has become a research organisation resulting from the merger of 8 research organisations, including Fundación LABEIN (the team involved in this proposal), which already changed its name to TECNALIA on Sept. 2010.

TECNALIA has a wide experience in Cultural Heritage issues, mostly in Immovable Heritage. As a private research centre close to market application, it has been involved in several research projects dealing with Cultural Heritage issues, at both National and European level.

TECNALIA has expertise in developing high performance products for the construction sector using nanotechnology and has a wide range of knowledge and experience on the synthesis, fictionalization, dispersion and characterization of nanoparticles and nanocoatings. In addition, TECNALIA has developed R&D European and national projects in the assessment of surface treatments for cultural heritage (CH) materials, being FP6 "*Graffitage*" project one of the most relevant examples. Besides, TECNALIA has expertise in real assessment of commercial

treatments on CH materials (mostly stone, bricks and mortars), and has performed practical work on more than 150 Spanish and Latino-American Monuments (from the Roman period to the XIX Century).
As coordinator in 3 Cultural Heritage related FP6 projects: GRAFFITAGE ("Development of a new antigraffiti system, based on traditional concepts, preventing damage of architectural heritage concepts"), OPERHA and CHRAF. In FP7, also on CH, participation in TEACH ("Technologies and tools to prioritize Assessment and diagnosis of air pollution impact on immovable and movable Cultural Heritage") and CHIC (Cultural Heritage Identity Card) and an SME project, EFFACEUR.
Tecnalia has experience in IPR protection, patents licensing and creation of spin-offs to uptake project results into the market.
Member of the ECTP, it is participating in five of the six of the Focus Areas of the ECTP and it is coordinator of the FA Cultural Heritage. It is also participating actively in the Spanish Construction Technological Platform co-leading the Area of Cultural Heritage.
TECNALIA has undertaken a socio-economic impact analysis of Cultural Heritage related FP5-FP6 projects, and it was coordinator of the exhibition salon of the 8th EC Conference on Sustaining Europe's Cultural Heritage.

1.5 Rete Europea Dell'Inovazione S.r.I (REDINN), Italy

REDINN is a European consulting company specializing in Innovation Consulting, Management Innovation and Innovation Strategy. The main aim is to accelerate growth through innovation. REDINN works in partnership with client to achieve outstanding sustainable results and implement winning innovation strategies.
With offices in Brussels and Rome and a network of partner companies over the EU countries, REDINN operates on many levels (Technology Audit, IPR, Technology Transfer, start up and SME acceleration). The services it offers are legibility assessment for Innovative products and process, the creative development of international and EU funding roadmaps, project ideas, project definition, planning, structuring and design, preparation of funding proposals.
The main activities are focused on three main areas of expertise:
1. Innovation policies and RTD studies;
2. Project management for Innovation and RTD related projects;
3. Consultancy services.

2. CONSORTIUM AS A WHOLE

The consortium represents a well-defined mix of competencies and expertise in the cultural heritage research sector in particular material science, to ensure successful project implementation and achievement of objectives by means of strengthening of cooperation capacities and research activities
The Jordanian partner will be in charge for overall project coordination and provision of know-how on technology of conservation of cultural heritage research sector, main actors and priorities in Jordan, while EU partners are responsible to provide access to EU networks and support capacity building of research centres. Critical mass for sufficient momentum to ensure self-sustainment and further development is achieved by comprising key complementarities between project partners.
The five partners will act complementarily towards the implementation of the project's objectives, through the following domains:

2.1 The Nature of the Activities

The consortium developed around three universities (UJ, POLITO, and METU) one SME (REDINN) and Research and Innovation Centre (TECNALIA). The activity of the partners covers the two objectives of reinforcement capacities in the fields of (i) EU-Jordan cooperation and (ii) S&T research qualities on related conservation of cultural heritage project topic. The consortium offers expertise and consultancy on applied research and international cooperation.

2.2 The Domains of Activities

In environmental monitoring, non destructive diagnostic tools, material science, and nanotechnology in art conservation. The whole grouping of these domains of activity shares the common theme of innovative technologies for painting wood conservation cleaning artworks, wall painting stones and metal artefacts conservation.

2.3 The Geographic Distribution

The partners of the project are from 4 Mediterranean countries (Italy, Spain, Turkey and Jordan).

2.4 The Equipment and the Used Tools

The consortium is well equipped on training, experimental analytical, monitoring, software and multimedia tools.
UJ has solid expertise in material research and proficiency in fostering sustainable international R&D cooperation through creation of partnerships and participation in various projects. Having experience in EU-funded projects, UJ takes a position of project coordinator. EU partners are R&D and innovation-focused organizations. Respectively POLITO, METU, REDINN and TECNALIA that are situated extensively within international networks, have rich experience in FP programs, capacity building, know-how and technology transfer. POLITO and TECNALIA have extensive in material science, electronic measurements and non-destructive diagnostic techniques research capacities and strong links to nanotechnology, ICT and material science research sector stakeholders within the EU, and therefore will provide a gateway for internationalization of Jordan conservation and cultural research centres. REDINN, TECNALIA, have outstanding expertise in the FP7 training, mentoring and coaching activities and will support capacity building of material science research actors in Jordan

3. PROJECT OBJECTIVES

The overall objective of JOCHERA project is the reinforcement of University of Jordan's cooperation capacities for cultural heritage research in the context of the European Research Area and development to the Conservation centre of excellence to respond to Jordan's cultural and socio-economic needs.
The specific objectives of JOCHERA project are:

- Better Coordination Between Policy, Research and Business in Jordan
- Enabling Better Participation in Framework Program
- Enhancement of EU-JO S&T Partnerships in Cultural heritage conservation
- Capacity Building for Solving Specific conservation problems and developing tailored conservation strategies

- UJ's Strengthening and Cooperation Capacities Reinforcement Establishment of a EU-JO conservation alliance and Results Dissemination

The reinforcement of the cooperation with Europe's neighbours in the context of of the European Research Area (ERA) is an important part of the EU Commission communication on the Strategic Framework for international S&T cooperation. This should complement the **Research and Innovation activities** described in the **National Indicative Programs** and covered by the European Neighborhood and Partnership Instruments (ENPI).

The improvement of international cooperation in research will create better conditions allowing research entities in Jordan, public or private, to better exploit and expand their research potential, thereby contribute to regional development by benefiting from the knowledge and experience in the EU and in associate member countries. Additionally, this project will also help to the neighboring countries in terms of their integration to the ERA. By focusing on the enhancement of the quality of the conducted scientific research in the selected research entities and by encouraging collaboration between partners and excellent research entities elsewhere in the EU, this project will contribute to the setting-up of strategic partnerships through FP7 project. Hence, this project will enable the Jordan partners to realize their full potential. This project will also help in reaching sustainable development and creation

4. OVERALL STRATEGY OF THE PROJECT

According to the Capacities – Work Program addressing ERA-WIDE, highest priority is given to strengthening and reinforcement of the cooperation capacities of research centres located in the ENP countries, which are not associated to FP7. The strengthening includes first of all *Twinning with research centres* in Member State/Associated countries, *Training* Activities, Capacity building Activities and also *research centre's strategy* activities. The JOCHERA will establish and implement a framework to reinforce the cooperation capacities and research activities in Jordan's Cultural Heritage protection sector by defining cultural heritage research priorities to respond to socio-economic needs, facilitating participation in European cultural heritage research initiatives and development of strategy for research centre based on thorough analysis of current situation, cooperation patterns, relevant actors, needs and opportunities.

In order to ensure a coherent and well-organised structure and implementation of the project JOCHERA consists of *five work packages (WP).* Every work package is under the responsibility of one WP leader. The work packages are subdivided into a number of *task***s** and *subtasks*, which are in turn related to concrete activities and deliverables. Each task will be organised by a *task leader* and executed with the help of the consortium partners attributed to the task. Every task in the work package will be handled with a significant degree of autonomy by the task leader. The work of the task leaders is crucial to the project since they will be responsible for the organization of the work in the task and for the preparation of the deliverables in time and in good quality. The task leaders will report to the respective work package leaders.

5. EXPECTED IMPACT

The JOCHERA Partnership will contribute to a systematic exchange of information, experience and best practice in order to establish comparable principles and standardised processes for joint multilateral activities. Additionally, harmonised IPR regulations, evaluation standards, jointly elaborated training courses, will be established to run possible future co-executed multilateral activities. The impact of JOCHERA is expected to be felt in the international sphere. Through the implementation of Work packages, the construction of a fully operational European Research Area on tangible cultural heritage preservation will be fortified and enlarged

JOCHERA will produce cooperation and support resulting in:

- Streamlining the capacity of UJ to coordinate its activities with European partners, and to actively participate in Framework Program activities. The project will address the strategy plan required to increase institutional visibility and RTD excellence at National, Regional and International levels.
- Fostering the capacity of European partners to cooperate with Jordan research institutions. The FP7 workshops and the other international events will permit to bring together local, Mediterranean and European institutions and public/private enterprises. These events represent the opportunity to present UJ organization to external potential partners for future joint research projects and cooperation activities.
- Integration with other FP7 project in the Region. As foreseen in WP1, twinning with other EU ERA-WIDE Project as well as with project funded by other donors, will be establish. This activity will be aimed to exchange information and/or perform common activities exploring the possibility to organize joint networking, dissemination events). In this way JOCHERA will permit to establish synergic effects

6. THE PROJECT ACTIVITIES

The JOCHERA activities are designed in order to reinforce the local capacity building for the participation in EU Framework Programme and to reach relevant impact on the increasing cultural heritage sector in Jordan.

The project will offer several capacity building opportunities using different tools in order to support UJ with all the necessary expertise it needs to became a competitive research centre with an Euro-Mediterranean vision and a well-established regional position

6.1 Study Visits

The study visits with the aim to increase the scientific collaboration between UJ and POLITO and UJ and METU through the exchange of knowledge and good practices**.**

6.1.1 First Study Visit, 28th March 2012: The first study tour in the project at the POLITO was for two employees of the UJ: Prof. Abeer Al Bawab (project coordinator), and Dr. Fadwa Odeh (researcher).The event was planned for three days and focused on exchange of knowledge and experiences in organization of research process. Prof. Al Bawab gave presentation about the history and culture in Jordan and the specific needs in the field of conservation of cultural heritage in Jordan. While Dr. Odeh, gave a summary of the projects that was conducted in Jordan in the field of conservation of cultural heritage and the methods used in conservation. A statement of collaboration describing the research directions and activities for exchange knowledge between the two partners was determined at the end of the tour.

6.2 FP7 Capacity Building Workshop and One to One Sessions

Innovative training workshops and one to one sessions will be foreseen into the project with the aim to offer to Jordan researchers the opportunity to experiment themselves in proposal writing and EU project management. Such events will empower the capability of UJ researchers and key personnel in check FP7 funding as well as other relevant EU funding opportunities, make trial on practical exercises based on successful projects as best practice examples, proposal writing exercises, practical and financial management of EU projects

6.2.1 First Training and Coaching Sessions 4-5 June 2012: The First training, aiming to explain the EU's Seventh Framework Programme for Research and Technological Development (FP7) and prepare to apply projects under upcoming calls for proposals.
FP7 Programme is the largest research programme supporting European and international research cooperation.
The next call for proposals will be announced 12th July 2012 with application deadlines in the autumn 2012 and in spring 2013.
FP7 is a very competitive programme, which offers large scale of participation opportunities, but also a very challenging competition.
Therefore submission of comprehensive and competitive high quality proposals is a necessity for being successful in this competitive environment. Researchers, who are developing proposals for the programme, need specific set of knowledge and skills, which JOCHERA project and this FP7 training is aiming at. The JOCHERA first training programme:

- Provide background knowledge about the European research funding system
- Train practical skills on how to develop a competitive proposal
- Offer continuous coaching support with guidance towards project collaborations and
- supporting the participation in FP7

6.3 Symposium

The aim of the symposium was to gather the academics, researchers, experts in cultural heritage conservation in order to discuss and analyze the current situation in Jordan and explore new ways of collaboration both at national and European level. The seminar's results will be collected in the Jordan's Cultural Heritage Symposium (JCHS) then a report, which will include the output of this symposium, case studies and best practices in Cultural Heritage conservation.
6.3.1 Conservation of Cultural Heritage in Jordan Symposium 6th June 2012: UJ/ HMCSR organized symposium entitled "Conservation of Cultural Heritage in Jordan, the symposium hosted many lectures and presentations. The participant in the symposium included a group of Jordanian and European researcher with interest in various approaches and aspect of cultural heritage preservation, and group of Jordanian governmental and nongovernmental policy maker of cultural heritage. The presentations varied from setting conservation and restoration laboratories, the global cultural sites in Jordan and the international standard for its conservation, innovation in cultural heritage, the monitoring sensors of temperature and humidity used in museums, to challenges facing the archaeology in Jordan,
Some of the listed speakers were:

The Director of the Centre, Prof. Abeer AL Bawab, pointed out that the cooperation with these partners allows UJ to benefit from the exchange of research and administrative experiences, strengthen its competitiveness and impact on scientific and applied research in the future by joint projects in the field of cultural heritage conservation in Jordan. Also, she listed some research projects relating to the cultural heritage conservation under the umbrella of FP7 that had been implemented over the past years. Emphasizing there is an urgent need to create a comprehensive database of these projects, analyzing the main objectives and the outcoming of these projects, to find out the cross section among them to avoid duplication, and finally to get some benefits from them. As a result a well defined road map will be available for the young researchers, enabling them to add missing fields and to create new projects in the field of cultural heritage protection.
Mr. Leonardo Piccinetti, the director of REDINN presented FP7 Capacities Programme – International Cooperation Activities ERA WIDE the presentation was with two aims first to compete nationally and internationally to attract the best teachers, researchers and students, second to compete for financial resources for research and infrastructure, as well as for contracts with business sector. Mr. Piccinetti also pointed out that there is an urgent need for a greater linkage and dialogue in the policy development of the European Higher Education Area (EHEA) and the European Research Area (ERA), particularly in relation to achieving a sufficient flow and supply of competent researchers. It is essential to ensure maximum synergies between the "Bologna Process" in building the EHEA and the parallel development of the ERA – "Viewed together, EU support through the Research Framework Program and the wider Bologna process represent a major investment in Europe's education, training and research sector to meet the Lisbon and Barcelona goals, notably in combating the present lack of qualified manpower.
Dr. Raghda kilani as the national contact point at the European Union presented an overview on the status of scientific research about science, technology and innovation in Jordan in addition to the local and international supports of the European Union.
The Dean of the Institute of Archaeology at UJ, Dr. Nabil Khairi, presented coins extracted from Petra that have been maintained and restored in the Institute laboratories under the supervision of the Head of Department of Cultural Resources at the Institute, Dr. Ramadan Abdullah.
The represented of the Heritage Committee of UNESCO in Jordan, Prof. Moawiyah Ibraheem talked about the challenges facing archaeological sites in Jordan such as urbanization at the archaeological sites and the increase number of tourists. Also he pointed out the need of developing a new strategy by experts in the area of cultural heritage protection in order to preserve the archaeological sites through raising the public awareness along with an emphasis in the nature of the laws and regulations that protect these sites.
Dr. Naima AL Husban from UNESCO in Jordan stated that the Organization's role in the protection of natural and cultural heritage is an essential part. Also, it will support projects that seek to preserve the heritage according to the global standards.
Dr. Alessandra Gandini from Fundacion Tecnalia Research & Innovation in Spain focused on conserving the Archaeological sites in the centre through the third International Exhibition for Spanish Archaeological sites conservation. Also, she talked about the centre's projects in the field of archaeological sites conservation.
The Secretary of Umm Qais Archaeological Museum in Jordan, Mr. Nasr Al-Zoubi tackled the Conservation and treatment of inorganic that were found from Umm Qais archaeological site,

Northern Jordan in 2009. Moreover, he pointed out that special materials have been used in conserving and protecting those according to the international standards and they has been saved in the museum warehouse in spite of the lack of, monitoring and controlling equipments.

Dr. Wasef Hawari from Yarmouk University expressed his worries about the way of dislocating mosaic floors discovered by the researchers during the process of archaeological excavations that affect negatively in terms of aesthetic, archaeological and cultural levels. He demands the need of the preservation the archaeological and aesthetic character of the mosaic floors through conserving and protecting them.

The most achievements of the symposium were:

- The gathering of Jordanian researchers interested in cultural heritage and their interaction with their European counterparts.
- The networking among Jordanian researchers themselves was initiated. Various points have been agreed upon as the outcomes of this symposium, these include
    - Constructing of a database for all researchers in the field of cultural heritage conservation in Jordan, and the symposium attendees can be considered as the seed for this database
    - Constructing of a database of all international and national projects in the field of cultural heritage conservation in Jordan that were performed in the past { the establishing of database, a technical glossary (techniques, materials and typologies) from the successive programs and projects covering cultural heritage research in Jordan, where the participants agreed at the importance of collecting all the results from the finished works that were concerning in cultural heritage in Jordan to get benefit from it and to complete the needs in preserving our heritage and improving our environment}
    - Evaluating the outcomes of these projects in order to better direct and plan ongoing and future projects concerned with cultural heritage conservation in Jordan
- Strengthen interaction and collaborative research between Jordanian and European researchers, universities, institutes and centers in the field of cultural heritage conservation in Jordan
- Introduce students (both graduate and undergraduate) to research in the area of cultural heritage conservation in Jordan and the various sciences that play a role in such a vast research area
- Proposing and recognizing some solutions for the potential, lacks and needs of governmental and nongovernmental sectors in Jordan dealing with cultural heritage and their implementation for the development of cultural heritage rational management and dissemination strategies and tools, and improvement of the conservation system in Jordan, to achieve a firm commitment to an integrated conservation strategy that balances the needs of various stakeholder.

6.4 Final conference

Final conference to represent project results, and, in particular, Cultural Heritage Conservation priorities for Jordan, will be organized in Amman by University of Jordan (HMCSR). Researchers, experts in Cultural Heritage conservation, cultural stakeholders will be invited to meet high-level EU representatives, policy makers, National Contact Points and successful project coordinators. The event will be extensively promoted and transmitted through various media channels (electronic, print and broadcast) within and outside of the Jordan.

7. REFERENCES

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9. FURTHER INFORMATION

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GREEN INFRASTRUCTURE EMBODY AN EXCEPTIONAL SPIRITUAL RELATIONSHIP OF PEOPLE WITH NATURE: CULTURAL LANDSCAPE, IMPLICATION FOR SUSTAINABLE DEVELOPMENT

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KEY WORDS: place identity, cultural landscape, green infrastructure, sustainable development, Pedhieos River

ABSTRACT:

The major thrust of this study is to identify a way to improve the physical condition of greenway corridors in urban areas to better serve the multi-objectives of greenways for sustainable communities, based on a literature review and case study. Pdios River has been introduced, because of several factors; it is geographically representative of the region and one of the main natural land marks in Lefkosa, capital city of Cyprus. This paper demonstrates that cultural landscapes are part of the city's wealth and producing healthy ecosystem as city's brand, with a proper designed green infrastructure planning, conservation and preservation, promote place identity in identified markets. Nearly all major cities have been built along river corridors. River corridors are being focused on as important natural networks as well as cultural and recreational resources. Lefkosa Creek passes through the historical old city of Lefkosa and another historic site so it provides historical heritage and protects cultural values. It can work as a recreational, educational corridor with attraction of the cultural, historical fabrics as well as ecologically significant corridors. This research paper presents the guidance report on how to develop the methodological work linked with green infrastructure to promote place identity by emphasis on conservation and preservation green infrastructure as cultural landscape as implications for sustainable development.

1. MANUSCRIPT

1.1 Introduction

This study provides empirical information useful in understanding how greenway trails in urban areas are perceived to develop designs that would improve the physical qualities of these trails. The study has two objectives. The first is to investigate with conceptual dimensions related to topics in order to make the required link between key words to understand the impact of culture on green infrastructure as transition of sustainability in searching for place identity. The second objective is to investigate the relationship between pieces and works to put all the pieces together in order to lead us into a design, as an example, Lefkosa Creek(Pedhieos River) has been introduced, because of several factors, on the one hand it is geographically representative of the region ,the Lefkosa creek watershed faces water quality and environmental challenges, it is one of the main natural land marks in Lefkosa; on the other hand, as a cultural landscape which became a vacant site and disused premises is a part of city's wealth, and provide a sense of place and identity; they map our relationship with the land over time; and they are part of our national heritage and each of our lives, a training ground and experimental zone for the future city. It is a physical reflection of the city's history. Reintegrating such spaces in the city, creating paths between them, reconnecting disparate urban spaces is something that can actively promote. Currently it has no market value. This study demonstrates that objectives, a healthy ecosystem, and sustainable urban aesthetic can be reached with a proper design in which the arts combined with other users. Amusement gardens with a juxtaposition of nature, art, food, dance music and dinner in a complex which Cultural ceremonies can be hold over there too. This approach is theoretical one so; a combination of documentary research and perceptive method could prove to be appropriate. In the process of devising theories, studying the urban planning texts related to the subject of study play a key role.

1.2 Place identity

Globalization is realized in uniformity of manners of behaviour but it is also coupled with plurality in identity that is manifested in various forms. Since modern communication techniques are costly and the majority of computer programs are American, the global village will be formed based on Western patterns. Today, non-Western civilizations show identity-safeguarding reactions against the waves of globalization, a mighty wave that no civilization is able to resist against or escape from it. We know that the process of globalization does not spell the end of ethnic, regional and national cultures. In contrast to globalization of the phenomena, bigoted nationalistic moves are revived. Allegiance to tribes and ignorant tendency to cultural identity are brought back to life. The cultural rhythm of the world is polyphonic and we are facing combinations and associations, the emergence of new thoughts and perfection of the ancient views. Myth is advancing shoulder to shoulder with wisdom. The most primitive culture is the essence of the most complicated technologies. All stages of consciousness, from Neolithic to the age of information, are seeking their rights. Their emergence puts forth another problem, i.e. their coexistence. Traditional thought is unable to get out of itself to criticize itself, but modernity is able to move on the heights of various levels of understanding and reflect a true evaluation with dependency on a certain culture. Globalization is an uncontrollable and irrevocable movement that came to being with the assistance of open market and development of transport and communications technology. In this age boundaries were removed, free turnover of properties and movement of individuals were facilitated, shocks were imposed on national devotion, and cultural identities were violated. The modern-day man has a fear in the depth of his heart. If he is the head of state, he will accidentally consult the palm readers and fortune tellers, and if he is a scientist, he likes to mediate on Tao physics and he believes in delicate things and metempsychosis. The modern-day man does not trust his wisdom and enlightenment. This is not spirituality anymore; it is the return of superstition. We are experiencing a schizophrenic behaviour. Accompanying with Japanese high-tech, we are going to prove “Chi” power in the school of Zen. New methods of education are introduced in cultural pluralism. Despite awareness on original identity, a new identity is created based on consensus and agreement. Instead of using pluralism we’d better use unity in multicipility, and then new and half-way education will have a new definition for itself. Identity as a fixed tribal unit will be rejected and from this viewpoint, identity is varied and variable in nature with a specific historical status, that is to say, it is the result of various changes, multiple-form and continuous distinctions. The followers of cultural pluralism attack this identity seeking nationalism. The most outrageous and critical attacks were originated by Foucault and Derrida. They bluntly attribute all valuation to the criteria imposed by the power structures.

With respect to the above, it becomes clear that the concept of identity in modern-day world is very complicated. Since the form created by man and his artificial atmosphere is the result of his thinking process and various forms and disciplines result from their way of mixing and because this thought has been organized in a highly complex cultural framework, if we believe in the role of city planner as a subjective factor in promoting the quality of city structure, we must identify the logic behind these relations in order to be able to expand this logic and obtain a conscious recognition for creating desired environment. Therefore, with respect to the studies of this paper in connection with the concept of identity and its multi-dimensional aspects, it is difficult to define a concrete meaning for place identity, but in general place identity is a reflection of indigenous identity, religious identity and global identity of its users.

1.3 Cultural landscape

Cultural Landscapes have been defined by the World Heritage Committee as distinct geographical areas or properties uniquely "..represent the combined work of nature and of man..".

The World Heritage Committee has identified and adopted three categories of cultural landscape, ranging from (I) those landscapes most deliberately 'shaped' by people, through (II) full range of 'combined' works, to (III) those least evidently 'shaped' by people (yet highly valued). The three categories extracted from the Committee's Operational Guidelines, are as follows:

(I) "A landscape designed and created intentionally by man";

(II) An "organically evolved landscape" which may be a "relict (or fossil) landscape" or a "continuing landscape";

(III) An "associative cultural landscape" which may be valued because of the "religious, artistic or cultural associations of the natural element". Cultural landscape, cultivated terraces on lofty mountains, gardens, sacred places ..., testify to the creative genius, social development and the imaginative and spiritual vitality of humanity. To reveal and sustain the great diversity of the interactions between humans and their environment, to protect living traditional cultures and preserve the traces of those which have disappeared, these sites, called cultural landscapes, have been inscribed on the World Heritage List. These certain sites reflect specific techniques of land use that guarantee and sustain biological diversity. Others, associated in the minds of the communities with powerful beliefs and artistic and traditional customs, embody an exceptional spiritual relationship of people with nature. There exist a great variety of Landscapes that are representative of the different regions of the world. Combined works of nature and humankind, they express a long and intimate relationship between peoples and their natural environment. Lands were then regarded to have been shaped by natural forces, and the unique details of such landshaffen (shaped lands) became themselves the subject of 'landscape' paintings (Gibson, 1989). A 2006 academic review of the combined efforts of the World Heritage Committee, multiple specialists around the world, and nations to apply the concept of 'cultural landscapes', observed and concluded that:"Although the concept of landscape has been unhooked for some time from its original art associations ... there is still a dominant view of landscapes as an inscribed surface, akin to a map or a text, from which cultural meaning and social forms can simply be read"(Pannell, 2006). Within academia, any system of interaction between human activity and natural habitat is regarded as a cultural landscape. In a sense this understanding is broader than the definition applied within UNESCO, including, as it does, almost the whole of the world's occupied surface, plus almost all the uses, ecologies, interactions, practices, beliefs, concepts, and traditions of people living within cultural landscapes(Flower,2003). Neglect and inappropriate development put our irreplaceable landscape legacy increasingly at risk. Too often today’s short-sighted decisions threaten the survival and continuity of our shared heritage. It is everyone’s responsibility to safeguard our nation’s cultural landscapes. The ongoing care and interpretation of these sites improves our quality of life and deepens a sense of place and identity for future generations.

1.4 Sustainable development

Development is considered a multi-dimensional process embracing not only economic but also social, political, cultural and environmental factors. It is a “continuous and positively evaluated change in the totally of human experience”(Harrison,1998)The concept of sustainable development means efficient use of resources, land, built space and energy and transition from using non-renewable to renewable resources. It means recycling materials and minimizing waste and pollution. It also includes limiting processes detrimental to heritage, nature and health and social equity. Finally, the concept rests on three pillars: environmental, social, and economic. In contrast to urban ecology, sustainability has no single theoretical starting point. The starting point for those working within the concept of urban ecology usually is fundamental environmental values and beliefs. They move upwards, mostly from local initiatives, with small scale projects and low level technology. Those employing the concept of sustainability have a pragmatic starting point and move along more rationalistic paths from the top downwards in large scale initiatives often involving a higher level of technology with responsible experts .The basic values in this perspective are to a large extent with a somewhat greater emphasis on the health and well-being of humans. The urban development of frontier economics leads to a number of environmental damages in the form of hazardous pollution, loss of recreational areas, etc. Within the environmental protection perspective, the need to counteract such damages is recognized if these damages are a threat to the health and well-being of the habitants. Through political tradeoffs one seeks to create an acceptable balance between growth and protection. In contrast to modernization theory, sustainable development gives primacy to the satisfaction of basic needs, such as food, shelter, healthcare and education, although economic growth remains a fundamental prerequisite-the pollution of poverty must first be addressed before development in form can occur. Thus, sustainable development proposes a long-term, holistic perspective that espouses equity, choice, political freedom (from dependency), cultural integrity and development within environmental parameters (Sharply, 2003).

1.5 Green infrastructure

A greenway is, in simplest terms, a linear open space. It is a kind of corridor composed of natural vegetation or at least vegetation that is more natural than in surrounding areas. The common characteristics of greenways are that they all go somewhere simply because, by definition, they are linear and natural. Greenways often follow natural land or water features like ridges or rivers, and link natural reserves, parks, cultural features, and historic sites with each other and with populated areas. A community's green infrastructure is a concept that highlights the importance of the natural environment in decision about land use planning. In particular there is an emphasis on the 'life support' functions provided by a network of natural ecosystems, with an emphasis on interconnectivity to support long term sustainability, while gray infrastructure consists of roads, sidewalks, buildings, and utilities. Now, green way planning has become a worldwide movement, and has been embraced by governmental agencies, non-governmental organizations and academies, but, perhaps most importantly, by citizens of urban areas and small towns. The focus is now on the demands of the increasing number of inhabitants and their requirement for recreational areas. Greenways are networks of land that are planned, designed and managed Greenways are networks of land that are planned, designed and managed for multiple purposes compatible with the concept of sustainable land use (Ahern, 1996).A comprehensive set of definition on greenway was provided by Charles Little, the author of the popular 1990 book *Greenways for America.* In this book a greenway is defined as: linear open space established along either a natural corridor, such as a riverfront, stream valley, or ridgeline, or overland along a railroad right-of-way converted to recreational use, a canal, scenic road, or other route. An open-space connector linking parks, nature reserves, cultural features, or historic sites with each other and with populated areas. Locally certain strip or linear parks designated as parkway or greenbelt (Little, 1990) perhaps the most widely accepted contemporary definition or statement on greenways in the USA was included in the report of the President's Commission on Americans Outdoors in the USA (1987). The Commission advocated a greenways network: to provide people with access to open spaces close to where they live, and to link together the rural and urban spaces in the American landscape threading through cities and country sides like a giant circulation system. It also reflects the late twentieth century orientation in contemporary American land preservation, which focuses on open lands that are directly accessible to population centres, in contrast with the nineteenth and early twentieth century emphasis on the great, but more remote, national parks and other protected landscapes (Zube 1975). The origin of greenway planning goes back to the 1700 till beginning of 20^{th} century. The first generation of greenways is the axes, boulevards, and park ways were affected from ceremonial medieval Roman Axes which were connecting seven churches as sacred way to each other to experience of sequential vision and linking fragmented site. Then magnificent axial boulevards effected from Baroque Planning to symbolize Empire power was designed (Baron Haussmann's boulevard planning) .In the United States, Fredrick Law Olmsted was well known. Patrick Abercrombie championed the idea of a Green Belt and Green Wedges around London. The second generation of greenways was reaction to industrialization and motorized route and was developed between 1960s and mid 1980s, as car became the dominant form of travel vehicle. Planner and designer were seeking, linear park and corridors, riversides, riparian ways, and all routes which were none motorized as an ideal proposal for protecting and linking a wide variety of cultural, recreational resources. With beginning of ecology movement in 1980, the concept of greenway changed. Organizations like Greenpeace were more radical, taking direct action against environmental destruction. Its views on people, behaviors, events centered around the political and lifestyle implications of the science of ecology and the idea of nature as a value in itself. "Ecology movement" is an umbrella term for different groups, ideologies and attitudes.According to Searns (1995), third generation of green ways are corridors of land and water that protect and link a wide variety of natural, cultural, and recreational resources. Greenways are corridors of protected open space that are managed for conservation or recreation purposes. They follow natural land and water features, like ridges or rivers, or human landscape features like abandoned railroad corridors or canals and link natural reserves, parks, cultural and historic sites with each other, in many cases with populated areas.

1.6 Pedhieos River

Over this long historic period the Nicosia has been a living legacy of the island's rich heritage and contains some of its finest example of byzantine, French Medieval, Venetian, Ottoman and British colonial architecture. At present Nicosia is divided by the buffer zone that keeps the Greek Cypriot and Turkish Cypriot inhabitants apart and splits their town into two separate urban parts, which have been developing independently of each other thus causing the disintegration of its entity. During the medieval period, until 1567Lefkosa Creek used to flow through the Venetian walled city of Nicosia, but it was later diverted outside and inside the newly built moat for strategic reasons, due to the expected Ottoman attack. From 1570 when the Ottomans took over Nicosia, the old river bed through the walled city was left open and was used as a dumping ground for refuse, where rainwater would rush through cleaning it temporarily. In 1882, during the British period, the old river-bed was covered for hygienic reasons (Attalides 1981). This Creek has wonderful ecological qualities. A sustainable tourism development is widely seen as a solution to the problem of island tourism. This may be achieved through more effective control over development at the national level, higher public investment in infrastructure, facilities and environmental improvements in resort areas in order to improve the quality of the overall tourist experience. Promoting tourism products successfully requires a context that allows the audience to appreciate what the country has to offer to visitors. That context is the overall image, or brand of a country. Therefore it can be utilized into creating and developing a new tourism resource such as an ecology tour for native plants while restoring the damaged ecosystem. It is promoted to grant a beauty of scenery and an environment friendly image of Lefkosa city. It secured a green space by using a stream, which serves as a buffing space between the old city and the new city designed for a learning place about ecosystem. It can also be utilized as an experience oriented class room where visitors can learn about the characteristics of habitats for different kinds of plants. It also helps the Lefkosa city promote its image as a garden city with a big scale greenway design . t is largely composed of a cultural experiencing zone, an ecology experiencing zone, and leisure zone.

2. DESIGN APPLICATION

2.1 Element of Pedhieos River

This part of research tries to show elements of a place which make strong image in different scale and level for promoting place identity as important factor in a space, so it is vital to recognize those elements. If we consider a place beyond something two-dimensional, like a living creature that has body and life. The Creek body can be studied in three scales of macro, medium and micro level and people, activities, smells, scents and sounds and other mental and sentimental as well as social, environmental, economical and political aspects that constitute a space in its generality.

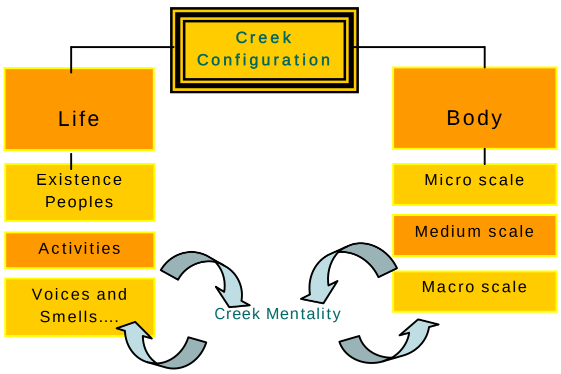

Table No.1 Element of Lefkosa creek

2.2 Macro scale: Evolvement of fabric in to the space

Since the approach to structure is in macro scale, it is free of details. Its components are either natural things such as topography, water, trees and vegetation, or manmade such as buildings and spaces, etc. These are seen from high-rise strategic points.

2.2.1. Components elements in macro scale

Entrances and Exits: Special design needs for entrance to create welcome feeling for visitors. In greenway design according to project division in different phase, symbolizes the main entrance through ornamental planting, using evergreen ornamental trees, which provide shades so it is used as a meeting and resting point, and traditional elements such as traditional main gate and fence walls. It offer leisure and sports space and consist of an exhibition and promotion theatre to attract the participation of citizens.
Solid and Void: Because of special topography, sculptural play of mass and space can be considered according to artistic principles.
Skyline and Silhouette: another important factor which in this scale make a strong image for percipient in reminding a place

2.3. Medium Scale: An image of visual factors which remain in percipient's mind

In this scale such factors should be interpreted that remain in percipient's mind as an image. These factors may be a single building, transitory, a borderline separating part, a tree, bushes, an attractive locality center or even the locality itself with certain features. In other words, such factors help the individual to read and find his way. Images associated with memories and meanings. They can provide the raw material for the symbols and joint memories and for group communications of the human beings. It is a natural panorama that leaves an outstanding memory in our mind, and creates a background that the majority of the primitive tribes have made their important social fables based on such foundation. These scenes are engraved in the minds of the beholders through the following factors (Lynch, 1997).

2.3.1. Components elements in medium scale:

Studies about component elements in medium scale consistently confirm Lynch's (1960) five types of physical elements, including:
Land mark: These are factors distinctive from their surrounding environment for reasons of antiquity, height, design, performance; etc. Creek can present symbolism and identity as Cypriot landmark
Networks Pathways: It is a factor that facilitates practical and potential movements such as trails, roads, sidewalks, roads, underground passageways, railways. These links encourages people to use alternative means of transportation like walking, bicycling and running. Greenway can be used as one way to harmonize various means of transportation and interweave the interaction of pedestrians and automobiles.
Edge: Another factor that divides part of a city from another part such as splits, railway, highway and rivers greenway. Creek as a natural edge offer leisure and sports space and consist of an exhibition and promotion theatre to attract the participation of citizens.
Node: Focal point of activity where people can gather and perform activities such as a park or public square are represented by nodes whereas physical objects that are considered to be only visual point of reference are represented by landmarks(Lynch,1960).
District: Illustrates medium to large parts of the city that are recognizable as having some common perceived character or identity such as an industrial area or a historic neighbourhood. Limitation encroachment of the riparian buffer zone through education, cooperation and incentive program. Keeping riparian corridor intact and continuous along the length of the stream.

2.3 Micro Scale: Those visual factors of body when is noticed immediately after entry the place

It is comprised of the clearest visual factors in a space that are seen immediately after stepping into the place. In other words, all observable elements seen at close range are classified in this category.

2.3.1 Effective Factors in this scale

Elevations: can be defined; the projection of the building which are by the side of Creek on vertical plane. The important factors in this scope are considered as follow:
Design, Method of construction, Construction materials, Colour and texture, Construction structure
Space: Space surrounded by mass, a breathing lung and openness. In relation with texture, they may open themselves or

be in contradiction with it. The spaces are classified into the following: Public, Semi-public, Private, Semi-private

Furniture: Floorings, panels, trees, plants, flowers, shelters, fences, lampposts, fountains, benches, kiosks, posters and announcements, boards, statues, post office boxes, garbage can, bicycle ridding signs etc. as urban furniture are considered in this scale.

Effective Factors in Improving Urban Furniture:
Design, Direction and orientation, Colour and texture

Mentality: The collection of container and content or body and life, which forms a place mentality.

3. AIMS, GUIDELINES, AND POLICIES

As a result the function of greenways are essential and due to scale, aims, context, views, lifestyle, income level, educational background and vocation situation and regulations which planner and designer consider is changeable .In respect of literature study and field study planning and design of Lefkosa creek as a place of tradition, culture and art with historical and cultural symbols can be considered a strong image of place identity in branding city. The concept of traditional culture has been adapted metaphorically from different sceneries related to the Cyprus,history,climate,geoplitical situation and etc.natural historical and cultural greenway can be defined in a broad sense. The aims, guidelines and different policies in design of Lefkosa creek as a cultural historical, Recreative greenway, changing scene, moving landscape, presentation of local /spatial identity can be summarized as follow:

Aim	Guideline	Policy
Convenient & Comfortable	Comfort of accessibilities	• Directness and fewer detours of bike lanes • Allow bicyclist safe access to main street • Quick transport, other destinations and safe crossing. • Bike lane pavement marking • Colored Bike Lanes • Separate Bike Turns Lane • Way finding • Less intersection between bicycle routes • Soft survey ,suitable ground cover • Suitable width of route
	Facilities Preparation	• Good intersection of routes to create suitable time sequential due to user favor
Safety Security	Against Vehicles	• Security & Safety for pedestrian • Suitable intersection of vehicle with pedestrian axes • Hierarchy of accessibilities • Suitable planting • Marking &signing
	Against dangerous &way characteristics	• At the beginning of way with marking, lead people to more safe way. • Existence of habitats, villages and cities for more safety if the green way is out of city • Lighting and open views
Continuity	Connected routes	• This is one of the important characteristics of greenways. Continuity between commercial center, habitats, public transportation, administrative center ,city center, schools, suburb, bus stations with the other pedestrians to create a network with continuity
Interpretation	Art of story telling with the spaces which greenways create	• Creating silence ness and calmness help for creation of interpretation space • creation more environmental perception with learning from nature, marking , signing , to create a space with identity and gravity
Vitality	convivial	• Pedestrians should be attractive with good design to promote environmental potential • Considering some spaces for restaurant markets and recreational places with enough lighting
	Mystery& delight	• With creation good curves or openings percipients will be lead toward some breather
	variety: In landscaping and form	• Landscape design with sequential visions by planting and using stone • Considering good elevations, colors, materials, to prepare variety as well as unity
	variety: In land uses	• Greenways should pass trough various land uses • Leisure spaces should be considered too
Way finding	Way finding map	• Creation internet stations to access GIS plans and information • Creation maps in the beginning each way for measuring time, distance, parking places, ramps, and the other characteristics
Universal design	Standards& Criteria	• Recreational stations and directions due to universal standards • Accessibilities for all ages and genders and classes • Sensory trails near parking for every body special for disables • Suitable ramps. To of the hill maximum %8(for 90 m length)and width ramp due to trail between%1-4

Table No.2 Aims, Guidelines, and Policies

4. CONCLUSION

Greenway are not only a tool to preserve and exhibit our past, they give the public access to historic feature while at the same time, provide educational opportunities and protect and preserve resources for future generations. This can be another solution for increasing competiveness by re-positioning Cyprus as a tourism destination; in particular, less emphasis to be placed on sun-sand tourism, whilst attention is to be focused on developing products, such as agro tourism, that are based around the island's culture ,natural environment and people. In general, marketing the island as a mosaic of nature and culture, a whole, magical world concentrated in a small warm and hospital island in the Mediterranean at the crossroad of three continents, between West and East that offers a multidimensional qualities tourist experience. Storm water design and management can be part of a larger plan for the revitalization of this area and to help direct future growth while improving the water quality and ecology of Lefkosa Creek.

Fig.1.Lefkosa Creek in relation with old City of Nicosia

Figure.2 Bird view of Lefkosa Creek

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NANOMATCH: A EUROPEAN PROJECT TO DEVELOP CONSOLIDANTS THROUGH THE SYNTHESIS OF NEW INORGANIC NANOMATERIALS FOR THE CONSERVATION OF BUILT HERITAGE

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KEY WORDS: Metal alkoxides, nanostructured materials, consolidants, biocides, built heritage conservation

ABSTRACT:

The problem of deterioration of historical building materials, namely stone, wood and glass has become more and more urgent. Climate changes have increased the impact of natural decay whilst socio-economic requirements claim a more sustainable use of existing built heritage. The EU project NANOMATCH addresses this problem through the development of a family of innovative materials. These are specifically designed for the consolidation requirements of historical substrates and for the production of high performance products to fill the gap in the market dedicated to the conservation of built heritage.
Metal-alkoxide precursors will be synthesized and their properties will be tuned based on the substrate characteristics of respectively stone, wood, glass to fulfil specific functionalities. The consolidation effects will be first evaluated through lab experimentation and subsequently the most suitable metal alkoxides will be tested in different European sites to evaluate also the environmental effects on their performance This will lead to a new generation of nano-products specifically tailored for historic materials in a context of climate change, emerging from the most recent and advanced research in the fields of conservation science and nanotechnologies. The development of suitable products for the treatment of historical materials will finally stop the inappropriate use of several commercial products, especially polymers. These have shown in recent years detrimental effects due to their fast deterioration and have also hampered the treated material as well.
Central to the project is the synthesis of molecular precursors, nano-coating deposition and assessment of their conservation properties leading to the production of innovative products for the market of conservation in replacement of unfit traditional ones. The basis for their production and market introduction will be developed within the project.

1. INTRODUCTION

1.1 Conservation challenges for built heritage

In a context of changing environment, the variation of natural and anthropogenic atmospheric parameters, i.e. rain, temperature, pollutants, are worsening the decay of indoor and outdoor monuments. Particular attention must be paid to these new risks (Sabbioni, 2007). Moreover the failure of most organic conservation/restoration treatments and the questionable efficiency of inorganic ones, emphasises the urgent need to develop new or to improve actual products and conservation methodologies as alternatives to conventional ones for Cultural Heritage.

Historic buildings are threatened by a great variety of natural deterioration agents (water, soluble salts and micro-organisms) and pollutants which can affect seriously the materials and their surfaces sometimes preciously painted or decorated. Moreover, the same factors acting on historic substrates will also be impacting on the treatment used. Organic polymers, for example, have demonstrated to be subject to weathering due to UV/sun radiation, water and salts, which reduce their efficiency and removability (Goudie, 1997; Ghedini, 2006).
From this perspective, it is necessary to take these weathering processes into account and not only design new compatible and resistant materials, but also define the most suitable ageing tests.

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1.2 State of art on available conservation products

Many products have been proposed and applied to mitigate the deterioration of building materials. They can be grouped in two main categories: organic and inorganic based products.
Several organic strengthening treatments, mainly consolidation, and materials have been used in order to restore original stone cohesion (Ashurst, 2006). Different synthetic organic polymers, i.e. mainly polyacrylate, polyvinylacetate, epoxy and silicones, have been widely used as consolidants and surface coatings for stone to prevent further deterioration since the last century (Price, 1996). These were not tailored specifically to the application on stone artefacts but seemed to respond to some of the main requirements of restoration treatments: reversibility, durability and chemical inertness.
Although they are still largely used, their conservation efficiency has been drastically reconsidered because they often failed on their promises. Severe alteration and degradation processes (such as photo-oxidative reactions leading to chain scission and/or reticulated structures in acrylic products, or hydrolytic and condensation reactions leading to stiff cross-linked structures in silicon-based products) induced either by environmental conditions or by the substrate itself, cause changes in the physico-chemical properties of those consolidants. In the conservation practice these result in a limited removability of the deteriorated polymers from treated surfaces (Favaro, 2006; Favaro, 2007). They are still in use due to the lack of more performing products notwithstanding the poor affinity with the substrate and/or cracking during shrinkage.

Also for wood there are many different chemical, physical and biological agents altering the lignin/cellulose content, going from a loss of mechanical properties to complete degradation of the wooden structure. Therefore, the investigation on new protective treatments/technologies to enhance stability, durability and service-life of wood-based construction materials is also required. Various approaches with organic compounds have been developed to improve the durability of wood under different environmental conditions. In order to protect wood from damage caused by moisture, it has been treated with waxes, resins (in particular acrylic resins, like for instance Paraloid B72). Often it has also been impregnated with toxic chemicals to prevent fungi or mould colonization (Kucerová, 2010). Net, intensive research is required to develop new environmentally sustainable technologies for improving the durability of wood.

Finally glass conservation was limited for a long time to mending broken pieces with lead and exchanging or referring glasses with degraded paint; later-on natural waxes, resins, animal glues and plaster of Paris were introduced. New perspectives were opened when the progress in the chemical industry offered new materials for gluing, protective coatings or paint layer fixing. However, all of those artificial resins were not specially developed for the application on ancient glass, but mainly for industrial purposes (Newton, 1982).
Since the 1950 ‘s various materials have been proposed and used for the conservation of stained glass, including epoxy resins, acrylates and polyurethanes, araldite and Paraloid B72 (Davison, 1984; Davison, 2003; Bettembourg, 1986; Henau, 1996). The all-round application has some drawbacks in many aspects, and the long-term stability of the treatments is for many materials still questionable (Bertelmann & Marschner, 1996; Jägers, 2000).
Only in the last years new materials were developed especially devoted to the conservation of stained glass (Roemich, 1992) (Trademark ORMOCER® or an inorganic polymer, called SZA). For the latter product, systems pilot studies are running, but no commercialization has been achieved yet.
Within the EU CONSTGLASS project, prototypes of innovative product were developed and evolved in a nano-porous glass-phase after sol-gel reaction and condensation (Bellendorf, 2010).

In summary, clearly evident and inappropriate interventions, all over Europe, resulted over the years in:

- cracking, scaling and flaking due to salt deterioration enhanced by superficial water repellent treatments,
- detachment of surface layers due to frost in treated materials, that were not showing frost damage prior to treatment,
- blackening, yellowing or discoloration of treated surfaces of buildings due to environmental and pollutant interaction with the applied products.

The reason for this lays mainly in two facts: the use of polymers conceived for other purposes and the impact of climate change on both historic materials and applied preservation products. Future maintenance, conservation and refurbishment will be facing higher costs due to the failure of polymer treatment or poor efficiency of inorganic product applications.

2. THE NANOMATCH PROJECT

The NANOMATCH project (Nano-systems for the conservation of immoveable and moveable polymaterial Cultural Heritage in a changing environment (2011-2014)) is a European Project of the FP7. A group of multidisciplinary experts (chemists, physicists, geologists and biologists) with conservators, restorers, producers and end-users will work together. 15 partners are involved: The Istituto di Scienze dell'Atmosfera e del Clima (Coordinator) and Istituto di Chimica Inorganica e delle Superfici of the Consiglio Nazionale delle Ricerche (IT), Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (NL), Fundacion TECNALIA Research & Innovation (S), Cercle des partenaires du Patrimoine-Laboratoire de recherche des monuments historiques (F), Fraunhofer-Gesellschaft zur Foerderung der Angewandten Forschung E.V (D), AIDICO-Instituto Tecnológico de la Construcción (S) together with the SMEs R.E.D. S.R.L. (IT), NANO TEGO INC. (TR), Bofimex Bouwstoffen B.V. (NL), Eschlimann Atelier de restauration – Peinture (F), T_O_P Oberflächen GmbH (D), SC DUCT SRL (RO) and the experimental sites Opera di Santa Croce Firenze (IT) and Metropolitankapitel der Hohen Domkirche Köln – Dombauverwaltung (D).

2.1 Aim of the Project

The overall NANOMATCH objective is the development of alkaline earth and semimetal alkoxides which evolve to nano-structured conservation products compatible with the main materials used in built heritage like stone and wood -even painted- and glass, ensuring enhanced sustainability, compatibility and efficiency compared to conventional conservation products.

The fundamental key S&T objectives of this project are:

to develop an alkaline earth alkoxide for stone and wood conservation and to prototype an already existing aluminium alkoxide product (developed in EU project CONSTGLASS) for glass consolidation;

to verify and demonstrate the higher performance of these new products in comparison with conventional and even new innovative ones currently available in the market;

to establish the most suitable methodology to apply these new products;

to assess their quality with respect to the environment and human health requirements;

to prepare more economically attractive products for the market, better meeting needs than current products.

2.2 The metal alkoxides for consolidation

Metal-alkoxides have great potential for the development of nano-structured materials, thanks to their high versatility of metal functionalization making them suitable molecular precursors for the preparation of metal-alkoxide solutions or nano-particulate inorganic sols. The final result is a sustainable product tailored to the needs of the material to preserve. This consolidated material would eventually become more resistant, with respect to current organic products, and also to environmental/climatic attacks, which differ from site to site. The consequence of this approach is the availability of more sustainable, specific and well performing consolidants, produced faster and at lower costs.

Particularly alkaline earth alkoxides, calcium and magnesium, precursors of corresponding carbonate, can be considered for stone strengthening as an indispensable and essential preliminary action for its conservation. Furthermore, the same material will be used for wood as these materials, besides strengthening effects, also ensure an alkaline supply to mitigate acidic deterioration processes of cellulose structures. As for wood it is desirable to enhance bioresistance and cohesion. The basic Ca/Mg alkoxides will be complemented via known technology with biocide functionalities by adding Zn/Cu, TiO_2 nanoparticles or organic molecules. For fractured glass consolidation, the promising aluminium alkoxides precursor of Al_2O_3, developed in EU project CONSTGLASS, will be further optimized and prototyped.

Alkaline earth and semimetal alkoxides are in fact suitable molecular precursors of consolidants for stone (Favaro, 2008), wood and glass because the corresponding solutions or nano-particulate inorganic sols, upon evaporation of the solvent based carrier, undergo hydrolysis and condensation or carbonation when inside the porous structure of the substrate. This was demonstrated for stones and wall paintings in feasibility tests performed in the bilateral Italian-French project GALILEO (Duchêne, 2012) (Figure 1). This results in the deposition of a nano-structured coating on the substrate pore walls (stone, wood) or in internal cracks (glass).

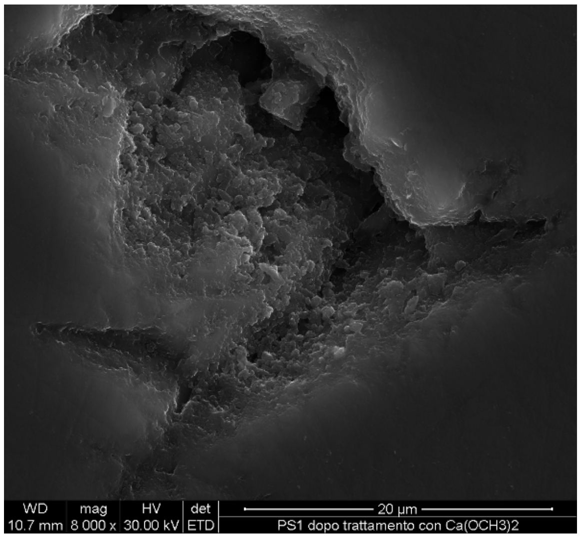

Figure 1: Secondary electron images collected by FEG-ESEM on marble treated with alcoholic solution of Ca-alkoxides. The homogeneous $CaCO_3$ coating has uniformly adhered on stone pore surfaces.

Besides that, the reacted compounds, carbonates and/or oxides, have the property to adhere well to the original minerals or wood structure of the substrate. By appropriate molecular tuning in function of the substrate requirements, they appear to be stable under major physical, chemical and microbial attacks, restoring integrity and (mechanical) properties of the original matrix.

2.3 Synthesis of metal alkoxides and Evaluation of their conservation properties

To reach these objectives the precursors will be designed by selecting appropriate reagents reacting with the alkaline earth metals Ca and/or Mg to obtain the desired consolidant for stone and wood. Different synthesis routes will be tested, according to the requirements of the selected final products through modification of organic substituents or through the doping with other metals or biomolecules, to obtain a biocide effect. For the already synthetized Al-alkoxide precursor of the glass consolidant the fundamental step will be the optimization of the sol-gel process deposition. Appropriate application methodologies will be developed and identified in laboratory, also avoiding detrimental effects (in terms of colour or structural changes) on any polychrome that might be on decorated surfaces or wall paintings.
After assessment of the applicability and workability of metal-alkoxides solutions, the compatibility of the nanostructured materials with the different substrates and their performance regarding the specific properties to be improved will be tested, and also compared to current commercial and other more recent preservation materials (Ksinopoulou, 2012; Maravelaki-Kalaitzaki 2012). Tests will be performed according to parameters established previously in the selection of substrates and in the acceptance criteria defined for compatibility and performance assessment together with a durability evaluation.
This lab experimentation will identify the boundary condition to perform a suitable conservation treatment taking into account 1. the effect of damage condition prior and environment condition during the treatment, 2. The influence of the treatment upon pore size distribution, structure, mineralogical and chemical composition of the substrates. Outputs from this work will be

the identification of suitable products and application methodologies to be tested on site on each substrate.

Field-exposure experiments will be performed on untreated and treated substrate models, eventually previously aged, to evaluate the synergistic interactions of environmental parameters with the substrates and to evaluate the behaviour of the innovative products also in comparison with the commercial ones. During this preliminary one-year survey, the best performing treatment will be tested on small areas of historic substrates to assess the effective interaction of nanomaterials on weathered surfaces. The compatibility effect on treated historic materials will be assessed on the basis of aesthetical, physical, mechanical, chemical issues. The treatment effects will be evaluated on on-going deterioration processes, on surface appearance, on variation of the hygroscopic behaviour that may differ with the exposure of adjacent untreated materials. An evaluation of risks & benefits as consequence of the treatment will lead to the definition of damage scenarios and associated risks as future damage development, based upon expert opinions.

As field test sites, four different urban locations in Europe were chosen in accordance with the different climate and environmental conditions of European countries (Figure 2):

- *Germany: Cologne Cathedral;*
- *Italy: Santa Croce Basilica in Florence;*
- *Spain: Oviedo Cathedral;*
- *Romania: Stavropoleos Monastery in Bucharest.*

All the selected monuments have the three different building material types, i.e. stone, wood and glass. Each of these monuments has particular regional features regarding composition, manufacturing technology and decay pattern. The preservation effects of alkoxides will be evaluated in all sites both on replicas, appropriately identified, and on real surfaces during 18 months to assess the climatological and environmental indoor and outdoor effects on alkoxides performance. At the same time, the same treated samples of previously chosen materials will be exposed in all the climatological regions to compare the effect of the different environments.

Figure 2. Example of different decay phenomena on outdoor stone materials in two of the selected sites: extensive biocolonization in Cologne Cathedral (Germany) (left) and surface dissolution and erosion on Stavropoleos Monastery in Bucharest (right).

Finally, their eventual safety hazards towards man and environment will be evaluated. Once their performance and safety has been verified, the prototype products will be produced and also the procedure for their introduction in the market will be defined.

2.4 How the NANOMATCH Project will advance the state of the art

NANOMATCH project is highly innovative and provides strong advances to the state of art for the following main reasons:

- the final products are new advanced compatible and sustainable nano-structured materials starting from the same class of compounds, tailored in relation to the conservation needs of the different substrates;
- the possibility of tailoring the precursors offers a variety of possible applications in producing products for restoration and protection of different types of stone, wood and glass;
- they are compatible with the substrates because the products have the same chemical and mineralogical composition as the substrate in the case of stone, while for wood and glass they are able to bond to the substrates because of their high chemical affinity;
- appropriate design of the molecular architectures will tune the final properties of the strengthening nano-structures in compliance with the physico-chemical properties of the substrates, without detrimental effect on any polychrome that might be present;
- their common base simplifies the process of the synthesis and the subsequent production of the final products;
- although not reversible, the products fulfil the most important requirements for a restoration product, i.e. compatibility, durability and retreatability;
- thanks to the chosen starting material, they are expected to be very low cost products;
- they are simple in the application methodology;
- an appropriate tailoring of the precursors of metal alkoxides and selection of the additives will tune the final properties of the resulting nanostructured materials to be effective towards the environmental changes.

3. FUTURE IMPACT

The NANOMATCH product will mark a new generation of restoration and protecting products, compatible with the original materials, applicable to indoor and outdoor Cultural Heritage.

The basic assumptions of compatibility and/or chemical affinity are at the basis of the expected positive impact in stone and wood applications. NANOMATCH will help to find the best solutions to slow down the damage process and provide tools to mitigate the incoming new mechanisms of deterioration. Thanks to their functionality and versatility they could be useful also in other applications such as tuning surface properties of metals, textiles, ceramics etc., enlarging the possibility of exploitation and market diffusion for the alkoxides derived products.

The new metal alkoxides, based on preliminary costs for production and application, have a promising potential which will be further explored within the project itself.
The starting materials, the precursors, are low cost materials. The synthesizing and subsequent production processes are well known and proven processes. In addition, as the metal-alkoxides constitute a common base for a wide range of substrates and as the fine tuning process is based on simple mixing and matching, the product costs are expected to be well affordable.
In fact, the idea at the base of the project derives from a concept used successfully in industry where basic components, so-called building blocks, are developed and then blended in different ratios to make up several final products adapted to different needs. This approach enlarges the potential use of the

technology in more markets and applications with economies of scale and cost reductions as consequence since the technological building blocks have to be developed only once. Metal alkoxides with consolidant and biocide products, in NANOMATCH project, constitute such building blocks for the industrial production and market distribution processes.
Since well-known synthesizing, production and application processes will be used like the controlled decomposition and sol-gel technique, the complexity will be of the same order of the existing products. However, due to the long lasting effects and the reduction of retreatability needs, the frequency and extent of application will be lower and hence the total cost.
Finally, as the application covers a wide range of substrates with their varieties, the economies of scale are expected to be higher than for the current products.

The increasing need to share scientific knowledge for the protection and conservation of cultural heritage at the European level is also addressed by the Project, in particular at a time when the environment is changing also as a consequence of political management. The project will promote close collaboration of SME professionals with researchers to steer basic research towards effective application in each development phase: development of suitable synthesis routes which can be translated into production processes, identification of application methodologies which are easy and safe to handle for conservation professionals (architects, restorers, contractors), formulation of compatible and durable innovative materials tuned to historic stone, wood and glass substrates ensuring a long lasting efficiency and reducing future maintenance costs after conservation.

NANOMATCH will enhance the co-operation between SME's, public and private research institutions on national and European scale and the potential benefit of the SME's. The project will create new, highly qualified and attractive jobs in the field of innovative material production and in added value services of historic material consolidation. It has the potential to create also new spin-off initiatives. Also indirect jobs can be created mostly linked to cultural tourism promoting social dynamism and conservation of historic urban areas and finally the quality of life of the citizens living in historic cities can be improved. In fact the visual effect that deterioration of historic surfaces causes in monuments produces strong societal impact. Built heritage deterioration and subsequent inadequate conservation causes heritage damage, insecurity to people living/visiting the affected cities and increases social degradation of cities.
The results obtained in NANOMATCH will certainly be of general interest and could be standardised and utilised by all the European States and not only the involved ones. The whole community interested on the conservation of Cultural Heritage in the world could be interested in this innovation that could strongly change the approach of the conservation methodology and strategy.

4. CONCLUSIONS

In conclusion NANOMATCH can provide a "new" category of compatible and sustainable nanostructured inorganic compounds with consolidant, protective and biocide effects. These will strengthen and preserve different damaged or weakened building materials, i.e. stone, wood and glass materials. Furthermore, their performance is expected to last longer than today's solutions available in the market.
The metal-alkoxides have either the same composition or a major chemical affinity and compatibility with the historic substrates in comparison to the products currently available on the market. The possibility to fine tune the product to the different substrates will further enhance the durability. Thanks to these characteristics, these products are inherently lasting longer.
During the project enquiries with SME's, restoration associations in several countries, large monument owners and associations of private owners of historical buildings will be done. This will not only confirm or increase the market potential estimate, but also provide further market insight to fine tune the research and improve the exploitation plans which seem to have a big potential in different scientific, societal and cultural fields.

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NANO-MATERIALS FOR THE CONSERVATION AND PRESERVATION OF MOVABLE AND IMMOVABLE ARTWORKS

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KEY WORDS: Conservation, nanomaterials, compatibility, durability, cleaning, deacidification, consolidation, nanoparticles, gels, low environmental impact

ABSTRACT:

In the context of the FP7 NANOFORART project (Nano-materials for the conservation and preservation of movable and immovable artworks) new nano-materials and responsive systems have been developed and experimented for the preservation of works of art. Conservation of cultural heritage is still mainly based on traditional methods and conventional materials that often lack the necessary compatibility with the original artworks and a durable performance in responding to the changes of natural environment and man-made activities. The main challenge of NANOFORART is the combination of functional materials arising from the recent developments in nano-science with innovative techniques in the restoration of works of art. The research activity has been focused on the development of manageable methodologies, based on nanosized structures and with a low environmental impact.
The main tasks include the production of dispersions of nanoparticles, micellar solutions, microemulsions and gels, in order to offer new reliable pathways to restore works of art by combining the main features of soft and hard-matter systems for cultural heritage conservation. Great importance was also given to technology transfer to SMEs that will play an important role in the standardization of applicative protocols, in the up-scale and commercialization of technology and in the evaluation of the eco-toxicity of nano-materials. Important museums, such as the National Museum of Anthropology and History of Mexico City and the National Museum of Denmark, are validating the technology developed in the project, and providing training activities and dissemination of the developed techniques.

1. INTRODUCTION

1.1 Objectives

The FP7 NANOFORART project is focused on the development and application of novel nanomaterials and nanostructured responsive systems for the conservation and preservation of moveable and immoveable artworks. The project is coordinated by CSGI (Consorzio Interuniversitario per lo Sviluppo dei Sistemi a Grande Interfase - Center for Colloid and Surface Science) and includes a wide partnership of experienced Institutions, museums and enterprises.
As a matter of fact, while the progress in Materials Science has already produced sophisticated nanostructured materials, the conservation of cultural heritage is still mainly based on traditional methods and conventional materials that often lack the necessary compatibility with the materials constituting the original artworks and a durable performance in response to changes of environmental conditions caused by natural events or anthropic activities.
The main challenge of NANOFORART is thus the integration of sophisticated functional materials arising from the recent developments in Nano-science/technology with innovative and *ad hoc* designed techniques in the restoration and preventive conservation of works of art, with unprecedented efficiency.
On one hand, the research activity will be focused on the development of new materials and, on the other hand, on the design and optimization of suitable and durable conservation methods in order to provide restorers and end-users with innovative but manageable methodologies, based on nanostructured systems and with a low environmental impact.
The project will thus be focused on the production of dispersions of nanoparticles, micellar solutions, microemulsions and gels, to be used according to new reliable pathways to restore and preserve works of art by combining the main features and properties of soft and hard-matter systems, allowing the design of specifically tailored chemical tools for cultural heritage conservation and preservation.
While assessment of the developed technology on real and widely representative conservation case studies and issues will be performed, the overall efforts will also be directed to technology transfer to SMEs and end users, that will play an important role in the assessment and refinement of the developed nanotechnology, in the standardization of applicative protocols, in the dissemination of the developed techniques and in the evaluation of the human health effects and environmental impacts of nanomaterials.
The general objectives of the NANOFORART project are summarized in the following points:

1. Design and formulation of “smart” nanostructured systems with special functionalities, which will include:

- deacidification of movable artworks (paper, parchment, textile, leather);
- cleaning of movable artworks (paper, parchment, canvas paintings);
- consolidation of immovable artworks (wall-paintings, plaster

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and stones);
- cleaning of immovable artworks (wall-paintings, plaster and stones);

with particular attention to the control of chemical functions in order to maximize the compatibility of materials with the treated artworks, and to the minimization of the use of high environmental impact products. The advanced nanomaterials and techniques (cleaning, consolidation, deacidification, pH adjustments) that will be developed within the project are compatible with the physico-chemical characteristics of artworks, and will secure the conservation of the original objects and/or improve the physical state of the damaged objects.

2. Physico-chemical characterization of the systems in order to understand and control the nature of the mechanism of interaction between the nanostructures and the target substances and supports.

3. Assessment of the applicability of materials in order to evaluate the contribution to preventive conservation and thus, implicitly, to the sustainability and authenticity of the cultural assets. In this phase a first scale-up of the technologies from the laboratory to the market level will be tackled. All the partners will interact in order to clarify and merge the priority from all the points of view.

4. Study of the long-term behaviour of the products and of the treated works of art by means of accelerated and natural ageing, in order to avoid damages due to unforeseen phenomena. The partners have their main competence in accelerated ageing of conservation materials, monitoring of environmental pollution, in particular emissions of volatile organic acids, and of art objects on display in museums and in storage. The proposal will thus assess the long-term behaviour of the materials as regards the durability of the historic assets and/or performance of the chosen techniques.

5. Development of industrial processes for the transfer of technology to market by the standardization of the applicative protocols and production of the nanomaterials on medium and large scale. Small and Medium Enterprise (SME) partners have their main competence in this area.

6. Evaluation of possible human health effects and environmental impact of nanomaterials for restoration. The technology generated by NANOFORART will be investigated with special emphasis on the potential hazardousness of nanoparticles used for design and formulation of nanostructured system and the environmental impact associated with the usage of developed nano-based products. Nanotechnology will significantly reduce the use of solvents and will introduce new environmentally friendly materials. The potential for adverse environmental and health impacts relating to the new materials and/or techniques will thus be assessed.

7. Dissemination of the developed technologies and training activities. In this phase a network of end users (e.g. museums, restoration public and private bodies, SMEs) will be built. End users will be active in both education and training activities as well as in the final refinement of the developed technology.

2. CONCEPTS

2.1 Progress beyond the state-of-the-art

Nanotechnology is revolutionizing material science in a pervasive way. The continuous development of novel nanostructure-based materials and the study of physico-chemical phenomena at the nanoscale are introducing new approaches to conservation science, leading to new methodologies that can slow down the degradation processes of works of art or even recover them from the damages introduced by detrimental restoration campaigns.
In the past few years CSGI (coordinator of NANOFORART project) has pioneered the development of new technologies for artworks preservation and conservation and has provided restorers with novel scientific and technological solutions to restoration and conservation problems (Baglioni 2006).
Within the NANOFORART project, new nanomaterials will be developed and assessed, both through restoration expertise by restorers, end-users and SMEs partners, and advanced analytical methods by partners as scientific centres and universities, in order to address different restoration issues involving conservation and preservation of movable and immovable artworks.
State-of-the-art nano-thermal analysis will be used for the first time in conservation science, in order to characterize the developed nanomaterials and their effects on the treated artworks. In the particular case of collagen-based artefacts, the proposal will benefit from the expertise of recent revisions of collagen structure at the nanoscale level. The structure has been described in terms of nanoscale ropes, providing new insight into collagen fibril structure (Bozec, 2007).
In the following sections important examples of the state-of-the-art knowledge in preservation and conservation of movable and immovable artworks, and the progress proposed by the NANOFORART project, will be shown, focusing on cleaning, consolidation and deacidification procedures.

2.2 Cleaning of immovable artworks

The state-of-the-art in cleaning procedures of natural or synthetic degraded and detrimental materials, such as adhesives, coatings, consolidants and protectives, is mainly related to the use of organic solvents and solvent gels (Wolbers 1989).
The traditional solvent cleaning is based on the identification of the materials to be removed, and on the selection of the solvent blend that maximizes the cleaning action. Teas charts are used to predict the power of solvent mixtures (Phenix 1998, Hiemenz 1997).
One of the issues in solvent cleaning of degraded natural or synthetic coatings is the loss of solubility of these materials due to molecular weight changes following their natural aging.
Another important problematic drawback related to the state-of-the-art use of solvents for cleaning immovable artworks such as wall-paintings, stone, plaster and stucco, is the re-dissolution of the natural or synthetic material into the porous matrix of the artefact.
Moreover, the usage of pure organic solvents increases the toxicity and environmental impact of the cleaning techniques.
The usage of solvent gels, first advocated in the 1990s, allows the localization of the solvent and, in some cases, the reduction of solvent's penetration into underlying paint layers. Unfortunately, it is not always easy to remove solvent gels and their residues from a paint surface and this problem will also be addressed in this proposal.
Recently, nanocompartmentalized systems tailored either for the specific removal of Paraloid B72 or of Mowilith DM5 (vinyl

acetate/n-butyl acrylate 65:35 w/w copolymer) resins from wall paintings, have been formulated by Carretti et al. (Carretti 2003). These systems are oil-in-water microemulsions (that from now on will be referred to as nanocontainers) or micellar solutions that ensure low aggressiveness with respect to the original components of the painted layer due to the presence of water as a dispersing medium that remains in direct contact with the hydrophilic surface of the wall painting. The large surface area of nanocontainers and micelles accounts for the strong interaction with the polymer coating, resulting in high detergency capability. Nanocontainers (whose dimensions are about tens of nanometers) provide a high solving power of the coating's layers, while micelles (whose dimensions are less than 10 nm) provide a fast swelling and detachment of the coating's layers at the interface between the coating's surface and the surface of the micelles. The detached coating's layers are then carried away in the micellar solution and hence removed. Both the solubility power and the swelling/detachment action are key-features for an improved cleaning and removal of the degraded coatings.

Compared to the traditional method based on pure solvents, nanocontainers and micellar solutions are very promising and offer better and faster performance, and decreased eco-toxicity and health risks, due to the fact that the percentage of pure organic solvents used in these formulations is usually less than 5% (water is the major solvent component of these systems, with a mass content 95%).

Another advantage granted by water-based systems is the reduced penetration into the immovable artwork's porous matrix with respect to the one that occurs with organic solvents. Hence, the polymer re-dissolution into the artefact is avoided.

Progress beyond the state-of-the-art in the NANOFORART project focused on the design and development of nano-structured fluids, such as nanocontainers and micellar solutions, that are specifically tailored for the simultaneous extraction of blends of different synthetic polymers or of blends of synthetic and natural organic materials used in past restorations.

In fact, Paraloid B72 and Mowilith DM5 have been very often used in mixtures or sequentially applied to wall paintings, so an ideal system should remove simultaneously both resins, in one-step cleaning process. Also blends of natural and synthetic materials are common in the state-of-the-art conservation practice, and this can have a detrimental result on artworks.

Oil-in-water (o/w) microemulsions, based on an anionic surfactant (sodium dodecyl sulphate) and 1-pentanol, have been obtained by using propylene carbonate and ethyl-acetate as a co-solvents.

The design of efficient formulations for the tailored removal of polymers requires a deep comprehension of the solubilization mechanisms, which can be more complex than traditional detergency, due to the presence of partially water-soluble organic solvents (cosolvents). One of the key features is the size of the nanocontainers and micelles: a smaller size results, for a given surfactant content, in a higher interfacial area that is correlated to the kinetics of the cleaning process.

The design process has been thus monitored by using scattering techniques (quasi-elastic light scattering, QELS, and small-angle neutron scattering, SANS) to optimize the size and the shape of nanocontainers and micelles, in order to achieve the best cleaning performance. Analytical investigations also granted a better understanding of the removal mechanisms and of the interactions between the nanostructured fluids and the artefacts. In particular, Atomic Force Microscopy (AFM) has been used to follow the first steps of solubilisation process at the nanoscale.

Parameters such as penetration in the artworks layers, the removal rate, the amount of removed materials and of left residues (surfactants) have been also investigated basing on the analysis of treated models and real samples.

Different cleaning case-studies of immovable artworks have been selected and faced, ranging from Northern to Eastern Europe and Mesoamerican areas. The selection was based on the representativeness *criterium*: the conservation issues considered in this project are, in fact, representative of the majority of real conservation case-studies.

2.3 Consolidation of immovable artworks

As discussed in the previous section, the most common practice in preservation of immovable artworks is nowadays based on the use of synthetic organic materials that very often are not compatible with the physico-chemical properties of the original artworks.

Given all the issues arising from the degradation of these coatings and from the lack of physicochemical compatibility with the substrates they are used on, the cleaning step is often a necessary preliminary phase for immovable artworks treated with such consolidants as acrylic or vinyl polymers.

After the cleaning, a new consolidation intervention, using compatible materials, will provide a more durable and compatible preservation and conservation of the artworks.

In the case of recently uncovered and yet untreated immovable artworks, on the other hand, consolidation is often the first step, previous to cleaning procedures.

The usage of compatible nanomaterials for consolidation of immovable artworks has been pioneered by the work of P. Baglioni et al. (Ambrosi 2001, Giorgi 2010a).

Materials such as calcium and magnesium hydroxide exhibit high compatibility with the surface of many immovable artefacts such as wall-paintings and frescoes, and represent an innovative and promising alternative to the usage of synthetic coatings.

Calcium hydroxide particles can be transformed into a material with excellent features as a consolidation agent, when synthesised as a nanomaterial.

In fresco painting consolidation, for example, nanoparticles of calcium hydroxide efficiently interact with carbon dioxide to reform calcium carbonate and replace the degraded original ligand, leading to the re-cohesion of the paint layer (Ambrosi, 2001).

In the NANOFORART project, progress beyond the state-of-the-art has consisted in the development of novel tailored nanoparticle-based materials for consolidation of wall paintings, stones, plaster and stucco.

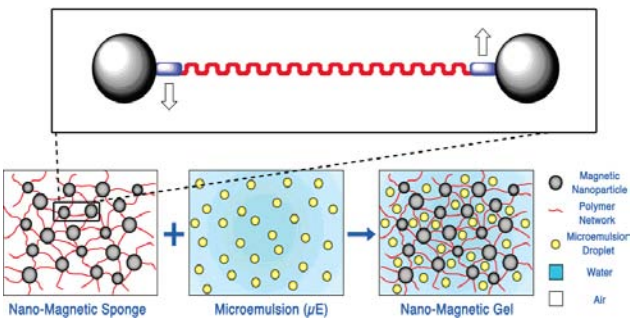
Figure 1. Scene from the "The Story of the True Cross" by Piero della Francesca (15th century), in Arezzo (Italy). On top, a pre-restoration image of the wall-painting. On bottom, a post-restoration image. Cleaning of sulphates and consolidation were performed by using the Ferroni–Dini method (Baglioni 2006).

The great diversity in the composition of artworks substrates, in fact, usually require the development of different formulations in order to achieve the maximum compatibility, both in terms of chemical composition and porous structure. Thus, each formulation have required specific procedures for the synthesis.
For example, in the presence of large amounts of sulphates (as contaminants), the consolidation effect of calcium hydroxide (that is the original binder of mural paintings) was enhanced by the complementary use of barium hydroxide nanoparticles, which leads to the formation of the totally insoluble, and therefore inert, barium sulphate (Giorgi 2010b) (figure 1).
For this purpose, it was necessary to synthesize particles with the same average size and highly similar particle size distribution, in order to avoid their clustering and separation. A top-down approach (by using high-energy milling) was followed to prepare barium hydroxide nanoparticles with average size of about 250 nm and size distribution compatible with calcium hydroxide particles, which are commonly synthesized through a homogenous phase reaction (bottom-up approach)
Progress beyond the state-of-the-art will be thus aimed at the design and upscale of several formulations of nanomaterials, that can be used for different consolidation issues, granting an easy use by restorers and a low environmental impact. Prototypes developed as demonstrators (not directly commercialized) in the framework of the project will hopefully provide fundamental information for possible (future) commercial exploitation of these technologies, specifically matching the requirements of conservation end-users.
As for the cleaning section, representative and world-wide transferable case-studies have been fundamental for the development of effective consolidation treatments for immovable artworks. Successful applications of mixed formulation of calcium and barium hydroxide have been recently done in the Maya site of Calakmul (Mexico).

2.4 Cleaning of movable artworks

Moveable works of art to be considered in this proposal include two broad categories: cellulosic (painting canvases, paper) and collagen-based materials (parchment and leather). Cleaning of moveable objects such as painting canvases, paper, parchment and leather artworks is particularly challenging since their physical and mechanical properties deteriorate with aging.

In the case of canvas-supported paintings, the state-of-the-art in cleaning procedures of the painted surface is mainly related to the use of solvent gels coupled with a wide range of solvents. The efforts in developing cleaning strategies have thus been pointing towards a complete and selective removal of dirt, degraded coatings, varnishes or adhesives and other detrimental materials, without affecting the underlying artwork's surface and bulk layers.
In order to obtain a better control on the cleaning action of solvents, gels and poultices have been increasingly developed in the last decades. Solvent gels developed by Wolbers, employing partially deprotonated (carboxylate/carboxylic acid forms) poly(acrylic acid)s (PAcAs) as gellants, have been the most frequently used to remove varnishes (Wolbers 1989). The application of solvent gels is relatively easy and their effectiveness is often high, but they might leave residues on artworks that are hard to clean without damaging the substrate's surface (Stulik 2004).
Starting from the Wolbers ideas, the need of new formulations has arisen in order to get a full control in the confinement of either pure solvents (as happens in Wolbers' systems) and the more efficient and responsive nanostructured cleaning agents (micellar solutions, nanocontainers). Chemical and physical gels have been developed in order to sequester (rather than to gel) cleaning agents.
A new formulation of highly elastic viscous poly(vinylalcohol) polymeric dispersion (HVPD) for conservation applications by Carretti et al., enables the modulation of the HVPD adhesion to the art object by controlling the HVPD structure and its degree of cross-linking. After the cleaning action, the HVPD can be easily peeled from the painted surface without the addition of a second liquid component, as is necessary with the Wolbers solvent gels (Carretti 2009, Carretti 2010).
Other useful formulations for chemical gels include the recent development of nanomagnetic sponges by Bonini et al.. By adding magnetic nanoparticles to the gel's polymeric network, it is possible to make the gel responsive to an external magnetic field (Bonini 2007), allowing the complete removal of the cleaning gel from the painted surface without leaving residues and avoiding additional contact between the conservator and the artwork. The mesh size of the polymeric network (usually inhomogeneous domain sizes of a few tens of nanometers, and micrometric pores) can be controlled by tuning the induced cross-linking, granting control over the compartmentalization of the cleaning liquid phase that is embedded in the gel.
Highly viscoelastic HVPDs and magnetic gels are very promising materials for cleaning movable artworks surfaces, but many questions remain about the range of their applications and the long term consequences of using them on artworks.
Progress beyond the state-of-the-art in the NANOFORART project have been focused on developing new chemical gel formulations, starting from the latest results, in order to make them effective in a wide range of different applications for cleaning movable artworks.



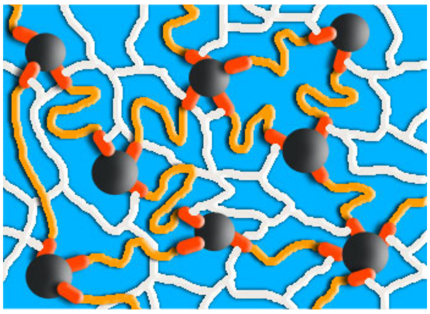


Figure 2. Schematic representation of the process of loading a microemulsion into an acrylamide-based polymeric gel structure. (top) Representation of cross-linked nanoparticles (black spheres) bonded to residues of maleic anhydride (blue rectangles) and a polyethylene glycol chain (red line). Arrows represent the binding group to the acrylamide-based polymer network. (bottom) The gel-particles network. Adapted with permission from (M.Bonini, S.Lenz, R. Giorgi, P.Baglioni, Nanomagnetic sponges for the cleaning of works of art, Langmuir). Copyright (1007) American Chemical Society

Diversification in the formulation of gels will be performed in order to adapt them to the sequestration of different nano-structured cleaning agents (nanocontainers, micellar solutions) and solvents.

The designed cleaning systems have been differentiated in order to achieve the maximum compatibility with the surfaces they were applied on. High-polarity cleaning systems (like hydrogels, oil-in-water nanocontainers or water-based micellar solutions), that work very efficiently for the removal of organic coatings from wall paintings, have been adapted in order to avoid drawbacks when applied on paper, canvas, parchment and leather (e.g. swelling of fibers).

High retention capability provided by chemical gels has prevented from risks of swelling and weakening of water sensitive support,s during cleaning.

Cleaning of canvas has been focused on tow main topics: cleaning of painted surfaces (canvas paintings, easel paintings) and cleaning of canvas surfaces treated with adhesives (lined canvas).

In order to design the cleaning systems for canvas paintings, traditional painting varnishes have been considered, including natural varnishes (e.g. dammar, shellac, sandarac) and synthetic (e.g. regalrez, hydrocarbon resin).

In order to design the cleaning systems for canvas surfaces treated with adhesives, both real and model samples treated with adhesives, natural glues (e.g. animal glue, waxes, resins, "*colle de pate*") and synthetic adhesives (acrylic and vinyl copolymers) have been considered.

Investigations on the topology of the gel action (i.e., the depth and rate of cleaning action, especially as measured quantitatively and in situ) have been performed, by using electron (FEG-SEM) and atomic force microscopy (AFM).

As previously reported for cleaning of immovable artworks, widely representative case-studies have been faced in the development of cleaning tools for movable artworks: painted silk textiles, painted globes (treated in the past with adhesives), and poor *tempera'* canvas paintings. Preliminary testing have provided really encouraging results. The preparations here described will be also tested on samples, which will be made available from the previous EU project IDAP (Improved Damage Assessment of Parchment). The advantage of testing methodology on such samples is that knowledge is available on the physico-chemical state of these samples, also at the nanoscale level from atomic force microscopy (AFM) images and then quantification of these images, also from the IDAP project. Similarly leather samples will be provided by the School of Conservation, Copenhagen, which remain from the previous STEP Leather project.

2.5 Deacidification of movable artworks

As a matter of fact, acidity is one of the main causes of moveable artworks degradation.

It has recently been highlighted that paper objects are deteriorating rapidly because of, mainly, two interconnected degradation pathways: the acid hydrolysis of glycosidic bonds and oxidation (Wouters 2008).

The state-of-the-art in paper deacidification treatments includes aqueous and non-aqueous methods, the latter being usually less invasive since it limits or avoids the swelling of cellulose fibres.

Among the non aqueous methods, the Bookkeeper (Preservation Technologies, L.P.) is an effective method based on dispersion of mainly micro-sized particles of MgO in fluorinated solvents. This method presents several advantages, but also some drawbacks: when paper porosity is low a light whitening of the document surface may be produced due to the fact that the particles present in the Bookkeeper are not small enough to completely penetrate inside the paper. Moreover, in order to stabilize the magnesium oxide dispersion, high concentrations of fluorinated surfactants are used. These surfactants remain on paper and their long-term effects are not yet known (Zumbühl 2001).

Recent studies (Giorgi 2005) have shown that alcoholic dispersions of calcium and magnesium hydroxide nanoparticles can be used for the neutralization of paper acidity and can generate an alkaline reserve of carbonate (after the reaction of the hydroxide with CO_2 from air) that prevents further degradation.

This method has been so far positively welcomed. The main advantages rely in the nanosized particles that grant a good penetration inside the paper fibers and a quick carbonation due to their high surface reactivity. Moreover, no surfactants are used to stabilize the alkaline nanoparticles.

It has also been shown (Kolar 2003) that the catalytic activity of copper and iron ions is minimal when pH is around neutrality. This means that the decrease of the degradation rate of oxidation through Fenton reactions could be provided by a precise control of paper acidity/alkalinity.

When dealing with highly oxidised paper, however, it is particularly important to adjust pH around not too high values, in order to avoid alkaline degradation of the aged cellulose fibres.

As a progress beyond the state-of-the-art, the NANOFORART project has aimed at developing new nanomaterials for deacidification of movable artworks, and testing their performance, applicability and durability.

The most important advance is represented by the upscale of the materials and the development of prototypes as demonstrators (not directly commercially exploitable), which can provide the basis for future commercialisation and the implementation of the methodology in semi-industrial mass-treatments.

Synthesis and preparation of nanoparticles are in many cases time-consuming and big limitations in terms of reaction yield are usually shown. Recently developed procedures for calcium and magnesium hydroxides exhibit these drawbacks that make them not well adaptable to large-scale production.

In the framework of NANOFORART project new chemical routes, based on a bottom-up approach, have been investigated with very important results. Particles with a narrow size distribution and average size about 100 nm have been obtained.

Particular interest has also been focused in less aggressive formulations based on calcium and magnesium carbonates, in

order to gain the proper pH adjustment and to avoid alkalinity excess.
The concept of pH-adjustment to reach the ideal value for conservation is also particularly important when dealing with leather and parchment treatments.
In fact, it is well known that a high level of acidity is detrimental to such artworks, promoting degradation of the protein molecules of collagen through hydrolytic processes, but also alkalinity, on the other hand, could result in damaging the fibres.
For deacidification of movable artworks, highly representative case-studies have been faced in the context of the NANOFORART project. Special emphasis has been given to modern and contemporary manuscripts; in these cases, the presence of solvent soluble inks strongly limits the possibility to perform deacidification treatment. The selection of proper solvent blends, which are compatible with ink materials, has provided good results for a wide range of documents.

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MEMORI PROJECT:EVALUATION OF DAMAGE TO EXPOSED ORGANIC-BASED HERITAGE MATERIALS AND NANOFORART : EVALUATION OF NANOPARTICLE-BASED CONSERVATION TREATMENT

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KEY WORDS: varnish, parchment, leather, canvas linings, micro-thermal analysis, atomic force microscopy

ABSTRACT:

This paper presents preliminary studies and work in progress in the framework of two FP7 projects: MEMORI (Measurement, Effect Assessment and Mitigation of Pollutant Impact on Movable Cultural Assets – Innovative Research for Market Transfer) and NANOFORART (Nano-materials for the conservation and preservation of movable and immovable artworks). One of the aims of the MEMORI project is the determination of threshold levels of damage to exposed organic-based heritage objects as little is known about the impact of organic compounds, especially volatile organic acids, on organic-based cultural objects. In the previous PROPAINT project (Protection of Paintings during Exhibition, Storage Transit) it was recently demonstrated that levels of volatile organic compounds (VOCs) were often much higher in the micro-climate frames used to protect paintings than recommended levels. In this paper, examples will be given of changes observed in varnished strips exposed at selected sites. Studies on the effect on collagen-based materials will also be presented. Techniques used in both projects include Dynamic Mechanical Analysis (DMA), micro-thermal analysis (-TA), and atomic force microscopy (AFM). The NANOFORART project explores the effects of using nanoparticle-based conservation treatment on cellulosic and collagen-based cultural materials. It builds on previous work performed on deacidification of canvas paintings using conventional materials. For collagen-based materials, no previous conservation treatment using nanoparticles has been performed on historical parchment or leather objects. Preliminary work is directed at understanding the type of nanoparticles to use to improve the physicochemical state of collagen-based objects.

1. INTRODUCTION

1.1 MEMORI (Measurement, Effect Assessment and Mitigation of Pollutant Impact on Movable Cultural Assets – Innovative Research for Market Transfer)

Museums are required to provide control strategies, risk assessment, and preservation management for their collections. To fulfil this task they are increasing their use of protection enclosures such as showcases, microclimate framing with front glass for paintings and storage boxes for archival materials, in order to protect the objects from the impact of the environment. For this reason guidelines are required of acceptable levels of volatile organic acids for organic-based objects within these enclosures. The use of controlled microclimates is an environmentally friendly solution which can contribute to climate change mitigation as it can replace energy demanding climate conditioning using HVAC systems for whole cultural heritage building interiors. It is therefore important to facilitate the use of enclosures by assuring optimal conditions for the valuable objects they protect. To determine threshold levels of damage varnishes were selected as representative materials initially in the PROPAINT project (Dahlin, et al., 2010) and then in the MEMORI project [http:// www.memori-project.eu]. Varnishes should protect surfaces of paintings and other heritage objects and should not discolour and degrade readily. Parchment and leather were also selected as representative materials of vast collections of manuscripts and leather bound books in archives and libraries. Many of these are stored in oak containing repositories and are exposed long term to levels of volatile organic acids which exceed the current recommended preservation target (1000μg/m^3 for one year) and which is based on work performed on metals, in particular lead (Tétreault, 2003). The key aspect of damage to collagen-containing materials is the state of denaturation of the collagen in parchment and leather i.e the extent of gelatinisation as this makes the objects more vulnerable to any aqueous based conservation treatment. The previous IDAP project (Improved Damage Assessment of Parchment) (Larsen, 2007) established markers for extent of gelatinisation in accelerated aged and historical samples. The former included inorganic pollutant aged and temperature and relative humidity aged samples. The data provide a basis for damage assessment, and are used in the MEMORI project to assess collagen based materials subjected to exposure to volatile organic acids. Damage markers will also assist in evaluation of effects of conservation treatment in the NANOFORART project [http://www.nanoforart.eu (accessed 16 Aug.2012)].

1.2 NANOFORART project (Nano-materials for the conservation and preservation of movable and immovable artworks)

The NANOFORART project addresses movable and immovable artworks and the aim is to develop novel nanomaterials for cleaning, consolidation, and deacidification of artworks. In this paper reference will be made only to the movable artworks, in particular deacidification of painting canvases. Results shown are of preliminary tests performed on samples prior to the start of the project and recently re-examined. The effect of natural ageing following conservation treatment is also one of the aims of the project. Meanwhile new preparations of nanoparticles are in progress and their characterisation. Past studies have included conservation of the seventeenth-century Swedish warship Vasa (Chelazzi,et al., 2006). There it was demonstrated that wood acidity could be neutralized by calcium or magnesium hydroxide nanoparticles. An alkaline reservoir was formed inside the wood that protected it from further acid attack. The pyrolysis temperature of the cellulose was taken as the damage marker, where a decrease in the pyrolysis temperature correlated with a decrease in its degree of polymerization. Thermal analysis was also used to investigate the efficacy of wood de-acidification treatment with alkaline nanoparticles. Hydrothermally ageing, carried out on de-acidified Vasa wood samples demonstrated that de-acidification with nanoparticles facilitates protection of wood against further acid degradation (Chelazzi,et al., 2006).

In the NANOFORART project the challenge is to design nanoformulations for conservation treatment of manuscripts and bookbindings. So far there is some information on the interaction of nanoparticles, mainly silver with collagen. A recent paper has shown that silver reacts with collagen with the formation of a silver bridge linking two peptide chains (Ionita, et al., 2010). In another paper collagen model solutions were interacted with classical crosslinking agents and silver nanoparticles synthesized by chemical, electrochemical methods or by deposition on TiO_2. These nanosilver colloidal solutions and dispersion were applied to leather and resulting interactions assessed by FT-IR, atomic absorption and fluorescence spectroscopy (Gaidau, et al., 2010). The study revealed that nanosilver reacts with the collagen macromolecule inducing modification at the secondary structure level of collagen.

For cleaning of surfaces of movable artworks highly viscoelastic hydrogels and magnetic gels are being considered as promising materials. Cleaning of canvas will focus on two main topics: cleaning of painted surfaces (canvas paintings, easel paintings) and cleaning of canvas surfaces treated with adhesives (lined canvas). Cleaning issues for aged leather are rather complicated Many leather artifacts, are in fact damaged by unfavourable conservation and maintenance procedures. There are still a lot of uncertainties on the use of consolidation and chemicals used in conservation treatment. Commonly used maintenance products include fats and oils and can cause the following problems:

- Materials do not penetrate into fibres and only block the pores on the surface. This leads to problems in leather objects and interferes with the application of other maintenance products.
- Some solutions of fats can penetrate more deeply, but migrate back to the surface after drying of the solvent.
- Many of the fats and oils used for maintaining leather, become resin-like) in the course of time and contribute to the embrittlement of leather. In addition, to improve the preservation of leather the pH value of aged leather artifacts may need to be adjusted and stabilised to a slightly acidic level while considering any possible negative effects (e.g. detannage) (Larsen, et al., 2006). A fundamental factor is the preservation of the fibre structure and the increase in stability of the single fibres.

2. MATERIALS AND METHODS

2.1 Samples

For the MEMORI project varnish layers (about 30 m) were sprayed onto steel as in the previous PROPAINT project (Dahlin, et al., 2010). Resin and solvents were supplied by Kremer Pigmente, (Aichstetten, Germany) and samples were prepared at the School of Conservation, Copenhagen.

Mimosa leather was produced by the Forschungsinstitut für Leder und Kunststoffbahnen (FILK), (Freiberg Sachsen, Germany) for the MEMORI project according to the prescriptions formulated in the Environment Leather Project (EV5V-CT94-0514) (Larsen, et al., 1996). Leather was tanned with a condensed tannin using bark of mimosa (*Acacia mearnsii*). Small samples were provided from historical objects requiring conservation treatment. (IPCE Instituto del Patrimonio Cultural de España Madrid, Spain). Some preliminary results are shown of tests performed on samples from the leather bookbinding of the Psaltar, from the Cathedral of Guadelupe (Spain) 16th cent.

Samples of canvas were obtained from the original auxiliary canvas (loose lining) of Sir Edwin Henry Landseer's painting ['Study of a Lion' (c 1862), Tate Gallery N01350]. These had been removed during conservation treatment and were provided by Tate Conservation Dept. for deacidification treatment.

2.2 Methods used in MEMORI and NANOFORART projects

2.2.1 Controlled Environment Dynamic Mechanical Analysis (DMA)

The rationale for the use of controlled environment DMA is that it provides information on the change in mechanical properties with controlled increase of RH. In the IDAP project it was observed that where samples were more damaged then there was a measurable difference in the change in stiffness of the samples and in the change in displacement (Odlyha, et al., 2009). In the MEMORI project differences have been measured between unaged parchment samples and those exposed to acetic acid vapour (Odlyha, et al., 2011). This information will be useful for the NANOFORART project which will be using deacidification procedures and so will rely on proven methods of damage assessment for testing the efficacy of the conservation treatment. Samples of canvas and leather were tested using the following instrumentation and procedure. Prior to testing, samples were pre-dried for 24hrs in a desiccator. They were then mounted in the tensile clamp of the Dynamic Mechanical Analyser (DMA TRITEC2000B).

The Triton RH controller unit was used together with the DMA and the starting conditions were set to 20% RH and 25 ºC. Once the sample had stabilised under these conditions then the RH was increased at 1%/min until 80% RH and it was left at 80% RH for 30 min. and dehumidified to 30%RH. Sample dimensions were typically 5 (or 10) (l) x4.50(w) x 0.2 (t) mm.

2.2.2 Micro-thermal analysis (μ-TA)

Micro-TA uses an atomic force microscope in which the conventional tip is replaced by an ultra-miniature electrical resistor (Reading, et al., 2001). This provides a controlled heating facility for spatially resolved thermal analysis. Its use in the PROPAINT project showed that glass transition temperature (*Tg*) of varnish samples on steel strips exposed in microclimate frames and rooms could be measured (Dahlin, et al., 2010). In the MEMORI project micro-TA has extended the information on varnishes to include the effect of exposure to volatile organic acids. It has also been applied to parchment, initially in the IDAP project (Groot de, 2007). The technique showed that surface gelatinisation occurs in samples. The interpretation was based on markers for gelatinisation obtained in previous work using micro-TA on model collagen samples (Groot de, 2007; Bozec and Odlyha, 2011). It has also provided information on the behaviour of varnishes, resin mastic and Laropal A81, following acid exposure and the results will be reported at the forthcoming second European Workshop on Cultural Heritage Preservation, EWCHP (http://ewchp-2012.nilu.no, accessed 16 Aug. 2012. The Micro-Thermal analyzer (*μ*-TA 2990) (Explorer AFM with the micro-thermal analysis user interface (TA Instruments, New Castle, DE) with Wollaston wire probe was used. Local thermal analysis was performed between 20 and 300˚C at up to ten different locations on a 100μm x 100μm area using heating speeds of 20˚C/s. Temperature calibration was performed using polymer samples of known melting temperature. The softening of the material as it passes through its *Tg* produces a downward deflection of the cantilever.

2.2.3 Atomic force microscopy (AFM)

The protocol for imaging collagen fibres taken from parchment was developed in the IDAP project (Groot de, 2007). Damage categories were also developed in IDAP based on accelerated aged and historical samples which showed various degrees of retention of the intact periodic D- banding and fibril structure. A computer programme was developed to measure extent of intactness of the periodic D- banding of collagen in the entire AFM image (Groot de, 2007). Correlation was found between the obtained values and the measured shrinkage temperatures. Varnished surfaces have also been studied and revealed surface defects which formed after exposure to acetic acid vapour and ozone respectively (Dahlin, et al., 2010). AFM was performed using a Dimension 3100-Nanoscope 1v AFM (Veeco) for parchment. The Nanosurf® EasyScan 2 AFM was also used in dynamic mode to image the leather samples and is reported in this paper. It was fitted with a cantilever (Nanosensors PPP-NCLR) with a spring constant k_{tip} =48N/m, resonance frequency f_{res} =170kHz and a tip radius r_{tip}<10nm. Fibres from the leather were moistened in distilled water and allowed to dry on a glass coverslip. This was attached to a glass slide using double-sided tape supported on a metallic holder

3. RESULTS AND DISCUSSION

3.1 Analysis of varnish samples

In the MEMORI project micro-thermal analysis has been used for evaluation of the glass transition temperature (*Tg*). The *Tg* of the varnish is measured in terms of the downward displacement of the sensor in units of micrometers as it changes with linearly increasing temperature (Figure 1). Ten different locations in an area of 100μm^2 were tested. The varnish (Regalrez 1094) is a hydrogenated hydrocarbon resin and measured *Tg* of the control sample was within the temperature range 37-40ºC (Figure 1).

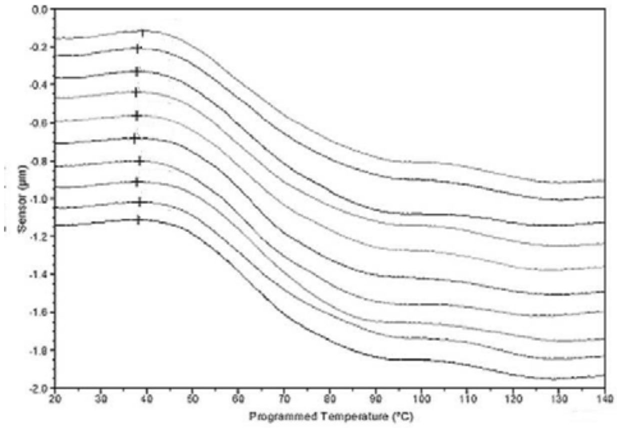

Figure 1 Sensor displacement (μm) vs temperature for unaged Regalrez 1094 varnish to give a *Tg* between 37-40˚C for 10 different locations in an area of 100 μm^2

On further curing and natural aging, the average value for the *Tg* moved to a higher value to 46.8˚C and this is shown in Figure 2 as the control sample (labelled HAc00). Exposure of this sample to acetic acid vapour (16ppm) produced further changes. Acetic acid vapour was generated from acetic acid solution and saturated salt solution (NaCl) to provide acetic acid vapour (16ppm) at an RH value in the region of 75%RH at room temperature.

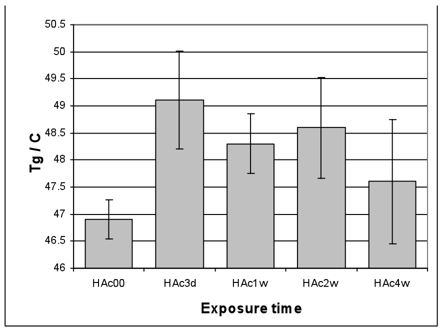

Figure 2 Change in *Tg* of Regalrez 1094 varnish with increase in length of exposure time (3 days to 4 weeks) to acetic acid vapour (16ppm) at 75%RH

Similar measurements on resin mastic and Laropal A81 will be reported in proceedings of the forthcoming EWCHP meeting (http://ewchp-2012.nilu.no). These resins show larger shifts in *Tg* for the same exposure. This indicates that Regalrez 104 is more stable with respect to acetic acid vapour than either resin mastic or Laropal A81.

Studies of resin mastic varnish strips exposed at sites were made during the PROPAINT project, in addition to accelerated ageing tests (Dahlin, et al., 2010). Some of the measurements are shown in Figure 3 for resin mastic varnish strips exposed in Cracow National Museum in two different microclimate frames for three months. One was a microclimate frame with low air exchange value (0.39) and the *Tg* of the strip exposed in this frame is shown as the 1st location (KNF). The value was similar to that of the control sample and was about 10ºC less than the sample exposed in another frame 2nd location (KL) where the air exchange value had a much higher value (14.9). This allowed ingress of oxidising pollutants (e.g NO_2). Strips exposed at other sites showed that differences could be observed between those exposed in frames and in rooms (Dahlin, et al., 2010). The micro-TA curves show that for location 2 (KL) there is evolution of more crosslinked material as there is a second *Tg* at higher temperature (Figure 3).

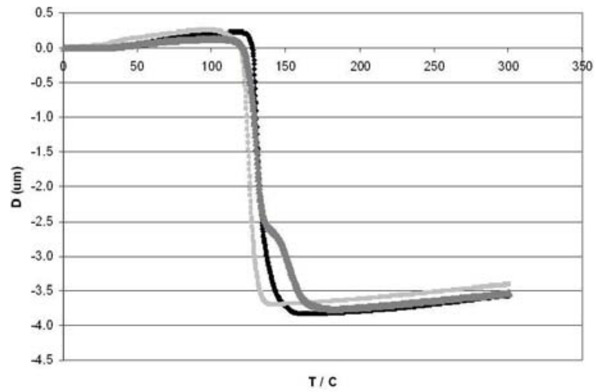

Figure 3 Micro-TA Curves showing displacement of sensor, D (m) vs temperature, T (ºC) control (light grey) microclimate frame (1st location, KNF, black) (2nd location, KL, dark grey)

Mass spectrometric measurements (MALDI-MS) (Figure 4) confirmed that this sample (KL) showed an increase in proportion of higher molecular wt. fragments. The fragment at (m/z) value (523) was selected as this has been assigned as indicative of presence of oxidation products of oleanonic aldehyde, assuming that oxidation leads only to new ketone groups (Scalarone,et al., 2005). Figure 4 shows the ratio of higher molecular weight fragment (m/z 523) to that of the lower molecular weight fragment (m/z 409) for varnish strips at selected sites where climatic conditions and pollutant levels (inorganic and organic) were tested during the period of exposure. These data are presented in the final report of the PROPAINT project (Dahlin,et al., 2010). In the two sites National Gallery of Denmark and the Museum of Fine Arts in Valencia,Spain, the change appears to be higher in frames than in rooms (Figure 4).

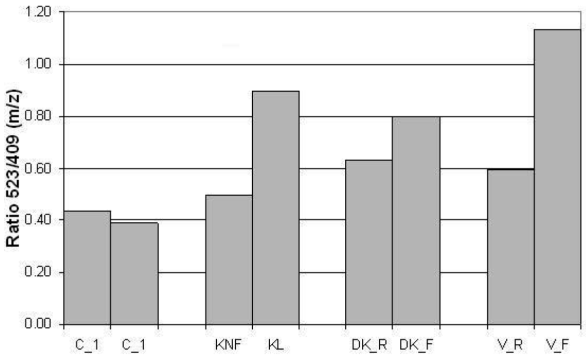

Figure 4 Ratio of fragment (m/z 523) to fragment (m/z 409) for resin mastic strips : C_1 (control), KNF,KL (Cracow National Museum), DK (National Gallery of Denmark) (DK_R room, DK_F in frame), V (Museum of Fine Arts in Valencia),Spain (V_R room, V_F in frame)

In the National Gallery of Denmark levels of acetic acid in the frame (DK_F) exceeded 1000 g/m^3. In the Museum of Fine Arts in Valencia, the *Tg* values measured by micro-TA were also higher for the sample exposed in the frame (V_F) than in the room (V_R) (Figure 4) . Dosimeter evaluations of these locations are discussed elsewhere (Grøntoft, et al., 2010).

3.2 Analysis of leather exposed samples

Controlled environment DMA was performed on pre-dried samples exposed for 4 weeks to acetic acid vapour (160ppm). The latter was generated from a solution of acetic acid (400mg/m^3) and saturated salt (NaCl) solution to provide 75%RH. DMA was performed using a sinusoidal load at a selected frequency (1Hz). This provides a measure of the complex modulus which can be separated into elastic (or storage) modulus (E') and inelastic (or loss) modulus (E''). Figure 5 shows the variation of storage modulus (E') for mimosa leather with RH (%) where RH is increased at a controlled rate on humidification and dehumidification.

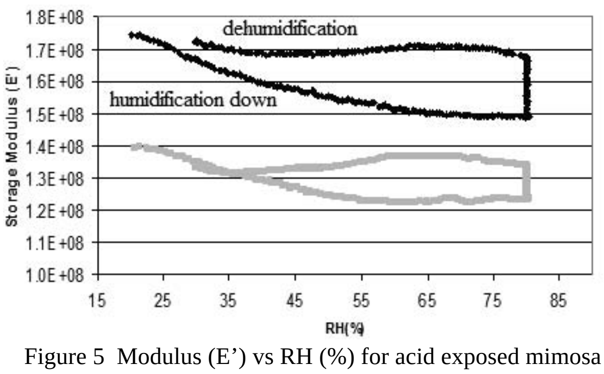

Figure 5 Modulus (E') vs RH (%) for acid exposed mimosa leather sample (grey) and control sample (black). Acid exposure causes lowering in modulus values. Time (100mins) spent at 80%RH produces smaller changes in modulus of acid exposed sample, and dehumidification shows some differences.

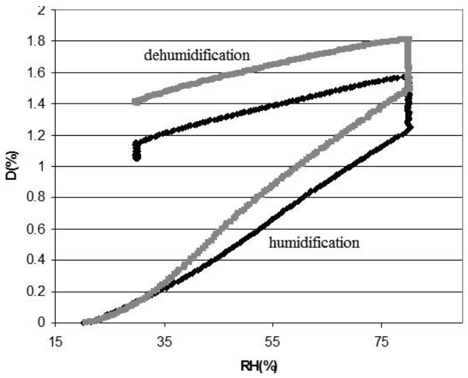

Figure 6 Acid exposed mimosa leather (grey) shows higher values of displacement (D%) with increase in RH (%) than in the control mimosa leather sample (black).

Figure 6 shows the change in displacement (%) of the mimosa leather sample with RH (%). Behaviour of leather appears to differ from that of similarly aged parchment. In the case of parchment the formation of a gelatine layer is often seen as a result of increasing deterioration whereas no surface gelatinisation of leather was observed. The gelatine layer develops from the hair holes on the grain layer and spreads until the surface is covered (Axelsson, et al., 2011). Preliminary work to assess the state of collagen in historical leather bookbindings (Figure 7) prior to conservation treatment has been performed in the NANOFORART project. Figure 8 shows AFM images with some regions of intact D-banding of collagen (Odlyha, et al., 2011) in areas in the inner cover.

Figure7 Leather bookbinding of Psaltar, Cathedral of Guadelupe (Spain) 16th cent. [IPCE Instituto del Patrimonio Cultural de España [Madrid, Spain]

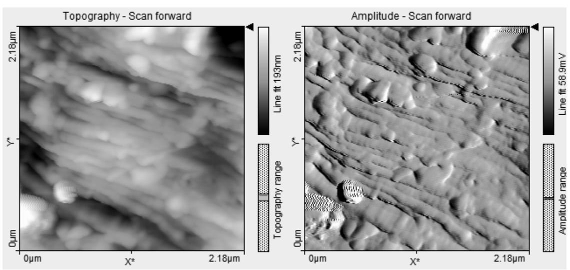

Figure 8 AFM (topography left) and amplitude (right) of leather sample from inner cover of bookbinding (2.18 m x2.18 m).

3.3 Evaluation of effect of conservation treatment on 19th century canvas linings

Deacidification of canvas paintings was previously performed in collaboration with Tate Conservation Dept. where reverse sides of selected paintings were treated with commercially available methoxy magnesium methyl carbonate (MMC) solution (Hackney,et al.,1996). Modern commercially primed and unprimed canvases were also treated and dynamic mechanical thermal analysis testing was performed (Odlyha, et al.,1997). Measurements showed that the treatment affected the mechanical properties. It appeared to produce a coating on the samples which acted as a moisture barrier. Recent preliminary tests prior to the NANOFORART project using both calcium and magnesium hydroxide nanoparticles on 19th century linings were performed and the effect of natural ageing of about two years is reported. The treatment is described elsewhere (Chelazzi, et al., 2006). In the NANOFORART project, work is ongoing to optimise nanoparticle preparations to solve the acidity problem, with particular attention to avoid swelling of the cellulose fibres.

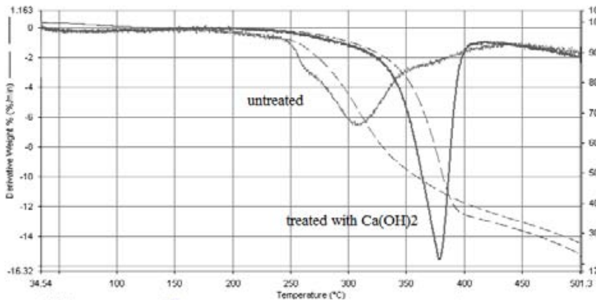

Figure 9 Thermogravimetric 1st derivative curves (full lines) with the thermogravimetric curves (dotted lines) of untreated and treated samples of 19th century canvas linings are shown

Figure 9 shows the effect on canvas linings of conservation treatment using alkaline nanoparticles [$Ca(OH)_2$]. The method uses thermogravimetry (TGA) which records the weight change in the sample with linearly increasing temperature. This was the method used to test the efficacy of conservation treatment on wood samples (Chelazzi,et al.,2006). Figure 10 shows the variation in modulus before and after treatment with increase in RH (1%/min). The sample after treatment appears to behave more like unaged canvas in its response to RH. Further work is in progress.

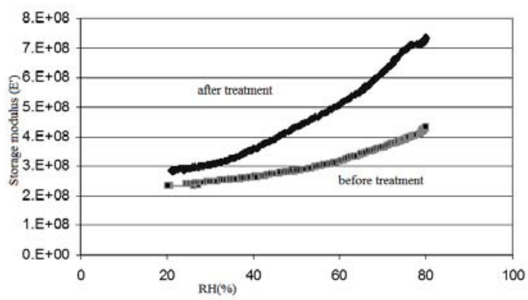

Figure 10 Changes in behaviour of E' (storage modulus) with linearly increasing RH(%) are shown for treated [$Ca(OH)_2$], and untreated 19th century samples (Tate Conservation Dept.)

4. CONCLUSIONS

This paper demonstrates that damage markers obtained in previous projects, PROPAINT and IDAP, are of use to current projects. The application of minimally invasive techniques such as micro-thermal analysis and atomic force microscopy are vital in characterising surface changes and complement additional information from controlled environment DMA and thermogravimetry (TGA). In MEMORI studying the effect of acidification of materials provides additional markers of damage that can be of use when evaluating effects of deacidification treatment in the NANOFORART project. Preliminary tests reveal that the effect of alkaline nano-particles improves the thermal stability of the canvas linings and changes the behaviour of the elastic or storage modulus with RH(%) making it behave more like the unaged canvas. The work is at an early stage and nanoparticle preparation is currently being optimized.

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ASSESSMENT OF LICHENS' METABOLIC AND DEGRADATION PRODUCTS AT DORNAVA MANOR

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KEY WORDS: Lichens, Stone objects degradation, Raman microscopy, Pulvinic acid derivatives, Oxalate degradation, Dornava Manor

ABSTRACT:

Five major types of lichen were discovered in the investigated specimens from Dornava Manor. All these lichens and/or their combinations are considered common lichenous overgrowth for the region and its climate. For all of the positively identified lichen species, it is common that they are found on a wide variety of calciferous or base-rich substrata, incl. mortar, brick, roofing tiles, walls, also in large urban areas (are not particularly disturbed by pollution/eutrophication), therefore preferring neutral to basic environment. They are well adapted to sunlight (from scarce direct solar irradiation to sites with very high direct solar irradiation) and can tolerate low water accessibility.
In some of the lichens parietin, an orange organic pigment, was found, indicating the sun exposed areas. Additionally, carotenoids and pulvinic acid derivatives were identified, from which the metabolic pathway of lichens can be determined. These products can also represent biomarkers that can be linked to the survival strategies of lichen communities in stressed environmental habitats.
For many of the investigated samples the lichens' degradation products like oxalates were identified, mainly calcium oxalate Weddellite, while the ammonium oxalate Oxammite is also possible.

1. INTRODUCTION

The Ba Fortress and Dornava Manor are the two historical sites with different backgrounds that were selected to be the focus point of the multidisciplinary research project HEROMAT, directed towards the development of innovative environmental friendly materials with value added functions aimed to the protection of immovable Cultural Heritage assets. The latter, where the investigation of lichens took part, is the ambitious house complex with accompanying park grounds, covering the area of approximately 3000 m^2, and one of the most important monuments of the late Baroque period in Slovenia. It was declared a cultural monument of national importance in the year 1999.

In the past years, the Manor has been studied thoroughly. The investigation, based on the research of archival sources and scientific research, gave a comprehensive image about the architectural history of the manor. It was constructed in many phases on behalf of different Styrian aristocratic families. Among these, the 18th century transformations of the manor are the most significant for giving the building its present form. It was completely rebuilt around the year 1700 by an unknown architect under the patronage of Count Franz Anton Sauer. The rebuilding was finished until 1708 when the ceiling of the Knight's Hall in the main wing was painted with a fresco showing scenes from the life of Hercules and his reception on Mount Olympus by Johann Caspar Waginger. In the first half of the 18th century, the property passed to the Attems family and the Manor was reconstructed once again. On behalf of Count Johann Thaddeus von Attems-Heiligenkreuz and according to the plans of an Austrian architect Joseph Hueber, two courtyard wings were added, new three-story façade with the representative central portal, altana and gable at the top was designed, and the Baroque gardens were constructed (Ciglene ki et al, 2003).

In the past, the Manor underwent some minor construction works, which over time severely damaged the building. Because of the long exposure to various environmental factors and in-appropriate restoration actions, the exterior elements (façade, statues and other ornaments) today show only a faint picture of the past splendor of the manor. After several decades of accelerated degradation, the overall revitalization of the manor is inevitable. Therefore, it was selected to be the subject of an in-depth research giving indicators that would stop further deterioration of the manor.

Studies of the biodeterioration of stone and similar (mineral, inorganic) materials are an important, and therefore extensively performed for decades, aspect of outdoor immovable cultural heritage protection and preservation. General stone biodeterioration research is superbly reviewed by Cutler and Viles (2010), and an excellent review of such studies, but focused on cultural heritage, is also available (Smith et al., 2011).

In the last decade, the development of analytical equipment has enabled analysis of stone biodegradation with only micro- or even non-destructive sampling. This approach to development is in line with the UNESCO WORLD HERITAGE CENTRE guidelines (UNESCO WHC, 2011) and is especially emphasised in the priorities of the EU Joint Programming Initiative (JPI) on "Cultural Heritage and Global Change: a new

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challenge for Europe". Moreover, several research grants have been awarded for the development of new materials and procedures for cultural heritage preservation, using these enhanced analytical techniques. One of them, a currently running and aforementioned project HEROMAT, is the frame in which the presented study was conducted.

The research by other groups has provided the information on several metabolic and degradation products that various (micro)organisms form during the colonisation of stone, and the importance of these substances in their survival strategies (Edwards et al., 2003a, 2003b; Frost, 2004; Castro et al., 2008; Kova ik et al., 2011). The following study presents the efforts to identify and characterise such products using spectroscopic techniques with only micro- or even non-destructive sampling, for better understanding of biodeterioration processes on stone, with the ultimate goal of enhanced immovable cultural heritage preservation.

2. EXPERIMENTAL

2.1 Sampling

The micro samples were collected from the different locations at the Dornava Manor. The sampling was focused on the stone elements and the facade surfaces with the render and colour finishing layers. The areas were selected according to their composition and expected degradation.

2.2 Lichens characterisation

Samples, removed for the analysis of biological growth, were investigated visually, using a stereomicroscope, and using a reflective microscope (Olympus BX 60), connected to a JVC 3-CCD video camera. Photographs of samples were taken using Visible light.

For the determination of lichen types or taxa a visual identification key was employed (Volkmar, 1995a, Volkmar, 1995b). Identifications were subsequently cross-referenced with images on the "ITALIC - The Information System on Italian Lichens" website (Nimis and Martellos, 2007).

After the determination of the present lichens, the samples were embedded in the polyester casting resin, then ground and polished. The cross sections of micro samples were then examined with an Olympus BX 60 microscope connected to a JVC 3-CCD video camera using Visible and Ultraviolet light.

2.3 Raman microscopy

Raman spectra of colour layers were recorded using 785 nm laser excitation line with a Horiba Jobin Yvone LabRAM HR800 Raman spectrometer coupled to an Olympus BXFM optical microscope. The spectra were recorded using 100 objective lens and 600 grooves / mm grating, which gave the spectral resolution of 0.83 cm^{-1} / pixel. The power at the samples was set between 3,6 and 35,8 mW using neutral density filters. A multi-channel, air cooled CCD detector was used, with integration times between 20 and 50 seconds, and the spectral range was set between 50 and 1800 cm^{-1}. The wave number calibration was performed using a silicon wafer. Spectra are presented with no baseline corrections.

3. RESULTS AND DISCUSSION

As a visual identification key was employed for the determination of lichen types or taxa, a well-developed sexual reproduction structures were required for positive determination on the level of individual species. Unfortunately, often the samples did not contain such structures (the lichen in the incipient stages of growth, etc.). In such cases, the determination was done on the genus level, or a broader morphological description was given.

Figure 1: *Caloplaca sp*. (sample DOR143).

Figure 2: Location of sampling DOR 143.

Overall, five major types of lichen infestation were discovered in the investigated specimens: *Candelariella sp. (C. medians, C. aurella); Lecanora sp. (L. albescens, L. dispersa); Caloplaca sp. (C. citrina)*; dark brown, dark gray to black-coloured crustose sterile cyanolichen (containing a cyanobacterium as a photobiont); un unidentifiable crustose lichen thallus. Figure 1 shows an example of identified *Caloplaca sp.* removed from a stone sculpture at Dornava manor site (see Figure 2).

Raman analysis of lichens is usually done by using FT-Raman systems and 1064 nm laser excitation (Schrader et al., 1999; Edwards et al., 1999, 2003a, 2003b; Castro et al., 2008; Gamsjaeger et al., 2011). Most of the enzymes and coenzymes of lichens absorb in the visible range of the spectrum and are photo-chemically sensitive, so the spectra are strongly overlaid by fluorescence even when those compounds are present in traces. Therefore, the use of a visible excitation (633 and 514 nm) gave no useful Raman data. However, by the utilisation of the dispersive Raman system with 785 nm excitation, it was possible to obtain some interesting results on the presence of pigments and metabolic products of lichens, as well as oxalates as a consequence of their degradation processes.

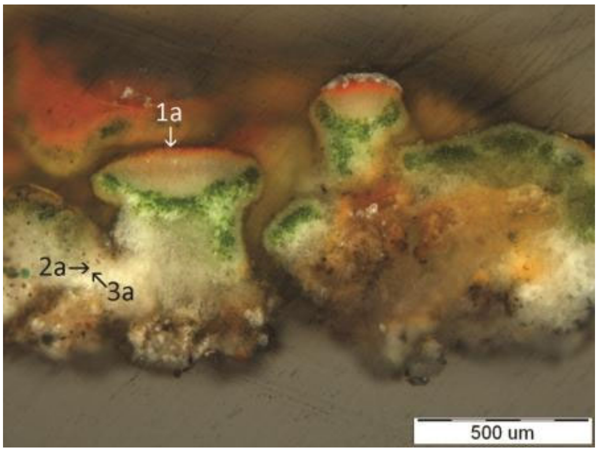

Figure 3: Photomicrograph of the cross – section of lichen prepared with DOR 143 sample, including locations (1a – 3a) of Raman analysis.

The Raman spectra of the orange areas (see for example Figure 3, analysis of spot 1a) of lichens were strongly hindered by fluorescence. However, the weak bands, shown in Figure 4, at 1669 ((C=O) conjugated), 1277 (in plane ring stretch), 928 ((C-H) out of plane), 467, 458, and 157 cm^{-1} correspond to the strongest modes of parietin (Edwards et al., 2003a). Parietin is an orange antraquinone pigment. A primary biological role of aromatic pigments in lichens is that of absorbing and filtering solar radiation, especially parietin and atranorin. The colour of lichen can appear from orange – red in highly illuminated sites and greyish yellow in shaded sites, due to the fact that the concentration of parietin is 5 times greater in the sun exposed areas (Edwards et al., 2003a; Solhaug et al., 2003). The orange colour of some lichens found at the Dornava manor site is therefore not connected to the presence of another lichen type, but dependent on the higher concentration of a pigment responsible for the colour.

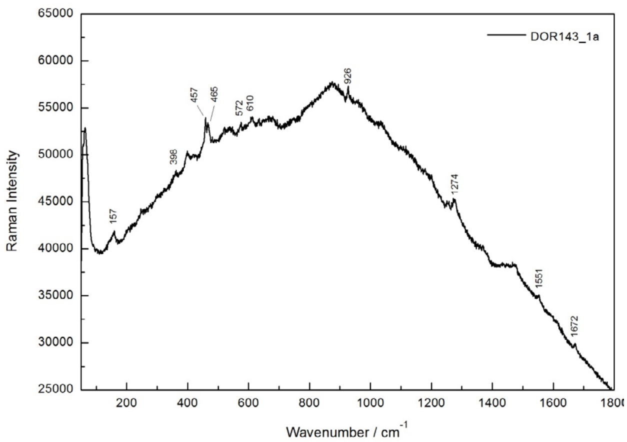

Figure 4: Raman spectrum obtained at the orange layer in the cross – section of DOR143 sample.

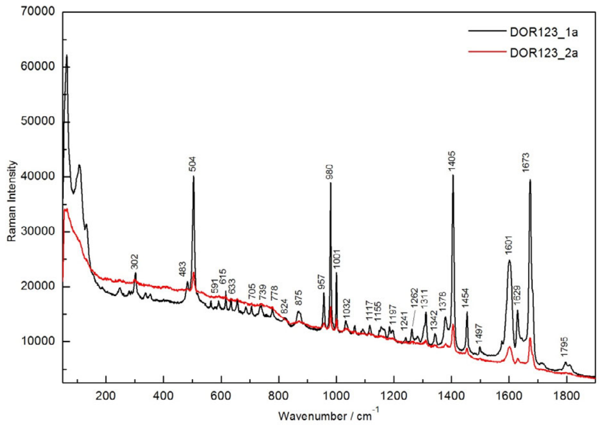

Figure 5: Raman spectra obtained at spots 1a and 2a on yellowish orange areas of sample DOR123.

On the other hand, the yellowish – orange areas of lichens present at Dornava can be correlated also to the presence of lichens' metabolic products. Analyses of such areas on sample DOR 123 showed the presence of pulvinic dilactone (Figure 5), with significant Raman modes at 1795 ((C=O) lactone), 1673 ((C=C) arom), 1601 ((C=C) furan), 1497, 1454 ((C=C) furan; ((CH_3)), 1405 ((CH)), 1311 ((C-O-C) lactone, conj'd), 1197, 1117, 1001((CC)), 980 (ring deformation), 824 (ring deformation), 739, 705, 615, 504, and 302 cm^{-1} (Edwards et al., 2003b).

The remaining bands of weaker intensity can be assigned to calycin, produced by lichens in the same metabolic pathway as pulvinic dilactone. However, due to overlapping with the strong signature of pulvinic dilactone the correlation with calycin is considered tentative, although the bands at 1629 ((C=C) arom), 1378 , 1342 ((COH) alcohol), 1262 ((CCO) as alcohol), 1241, 1155, 1032 (ring deformation), 957 (ring deformation), 875 (ring deformation), 778 ((CCO) s alcohol), 633, 591 ((CCO)furan), and 483 cm^{-1} are in good agreement with the Calycin published data (Edwards et al., 2003b).

For many green areas of the lichens' samples Raman spectra showed relatively weak bands, but still, it was possible to correlate them to the strongest modes of chlorophyll and carotenoids.

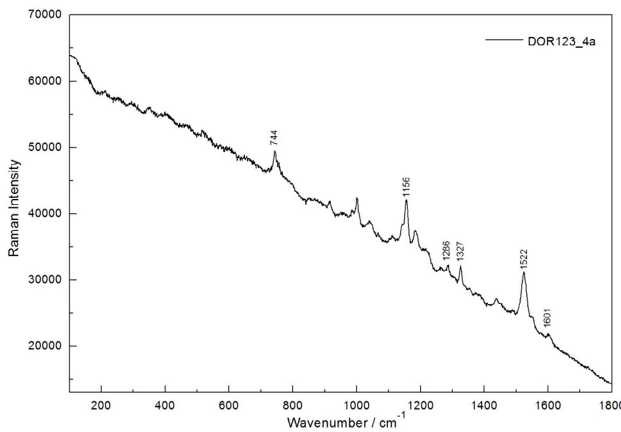

Figure 6: Raman spectrum obtained on a green area of sample DOR123.

Figure 6 shows the Raman spectrum recorded on the selected green area of sample DOR 123, with Raman shifts significant for the most intense modes of chlorophyll (1329, 1287, and 744 cm^{-1}) and carotenoids (1526, and 1154 cm^{-1}). Although the bands appear in weak intensities, these peaks were determined as markers for both substances by several authors (Schrader et al., 1999; Vitek et al., 2010; Gamsjaeger et al, 2011). Carotenoids are protective against photostress and oxidation. Additionally, they are also known as one of the metabolic products of the lichens following the mevalonic acid pathway, while pulvinic dilactone and calycin are pulvinic acid derivatives, one of the metabolic products of lichens when shikimic acid pathway is active. Depending on the environmental stress, the lichens will have different metabolic pathways employed, and their products can also represent biomarkers that can be linked to the survival strategies of lichen communities in stressed environmental habitats (Edwards et al., 2003b; Solhaug et al., 2003; Kova ik et al., 2011).

The above described Raman results on the presence of parietin, pulvinic dilactone, calycin, chlorophyll and carotenoids can give mainly the data on the environmental stress an object was exposed to, that needs to be taken into account for designing safe treatments for objects of cultural significance. But, the real damage, which needs to be addressed with caution, the lichens cause to these objects is the formation of oxalates, which were found in several samples from Dornava manor.

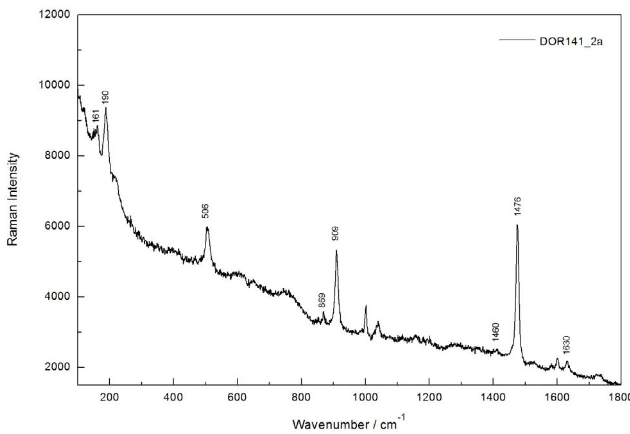

Figure 7: Raman spectrum obtained on the sample DOR 141.

Figure 7 shows the presence of the Calcium oxalate (CaC_2O_4 $2H_2O$) Weddellite with bands at 1630 ($_a$(C=O)), 1476 ($_a$(C=O)), 1460 ($_s$(C-O) + (C-C)), 909 ($_s$(C-O) + (O-C=O)), 869 ($_s$(C-O) / (O-C-O)), 506 ((M-O) + (C-C)), 190 (lattice modes), and 161 cm^{-1} (Edwards et al., 2003c; Frost, 2004; Castro et al., 2008). In some of the samples also the presence of the ammonium oxalate Oxammite ($(NH_4)_2(C_2O_4)$ H_2O)) is possible (spectrum not shown).

It is interesting to note that in all these samples lichens containing *Lecanora* sp. were identified, possibly implying that *Lecanora* is a strong oxalate producer (Edwards et al., 2003c).

4. CONCLUSIONS

Five major types of lichen infestation were discovered in the investigated samples: *Candelariella sp. (C. medians, C. aurella); Lecanora sp. (L. albescens, L. dispersa); Caloplaca sp. (C. citrina)*; dark brown, dark gray to black-coloured crustose sterile cyanolichen (containing a cyanobacterium as a photobiont); crustose lichen thallus.

All these lichens are considered common lichenous overgrowth for the region and its climate, and it is common that they are found on a wide variety of calciferous or base-rich substrata, including mortar, brick, roofing tiles, walls, also in large urban areas, and are not particularly disturbed by pollution/eutrophication. They are also well adapted to sunlight and can tolerate low water accessibility.

Utilising Raman microscopy, it was possible to obtain some interesting results on the presence of pigments and metabolic products of lichens, as well as oxalates as a consequence of their degradation processes. Some orange-coloured areas showed the presence of parietin, which is an orange antraquinone pigment, and its quantity can be 5 times greater in the sun exposed areas.

The yellowish – orange areas of lichens were correlated also to the presence of lichens' metabolic products (pulvinic dilactone and calycin). For many green areas of the lichens' samples, Raman spectra showed the presence of chlorophyll and carotenoids (also offer protection against photostress and oxidation).

Carotenoids are synthesised in a different metabolic pathway (mevalonic acid pathway) then pulvinic acid derivatives (pulvinic dilactone and calycin – shikimic acid pathway). Detecting and differentiating between these metabolites can potentially establish procedures of linking these biomarkers to the survival strategies of lichen communities in stressed environments.

The presence of parietin, pulvinic dilactone, calycin, and carotenoids can offer insight on the environmental stress an object was exposed to, which needs to be taken into account for designing safe treatments of cultural heritage in outdoor environment. However, the direct damage the lichens cause to these objects is the formation of oxalates, which were found in several samples (mainly Weddellite, possibly Oxammite). Interestingly, all these samples contained the lichen *Lecanora sp*., possibly implying that it is a strong oxalate producer.

The results obtained and the knowledge gathered during the research work presented in this publication will support and streamline future work within the HEROMAT project.

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THE CHOISE OF PARAMETERS FOR THE MONITORING AND THE MAINTENANCE OF ARCHITECTURAL STONE SURFACES

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KEY WORDS: monitoring, maintenance, threshold limit values, efficiency, protection, cultural heritage

ABSTRACT:

The maintenance of stone buildings aims to preserve artefacts, to reduce the economic management costs and to extend the lifetime of the restoration interventions. Up to now, there are no clear regulations regarding useful parameters which can be used for evaluating the efficiency of surface treatments for the consolidation and protection of stone. The main goal of this work is to identify possible important "chemical-physical parameters" and their threshold limit values. In this context, the determination of the surface water absorption and colour variation may be important tools for the control and the monitoring over time of the state of conservation of the architecture stone surfaces. These parameters are strongly related not only to the surface conservation state but also to products efficiency. Moreover, they can be easily measured at low cost by specifically trained personnel.

1. MONITORING AND ARCHITECTURAL SURFACE: DEFINITION AND MEANING

To evaluate and monitor the conservation state of an artefact is very complex as many different aspects are involved: the chemical-physical degradation processes of the materials; specific environmental conditions; non-invasive or possibly micro-invasive analysis; etc (Biscontin, 2009).

Recent studies have tried to estimate the risks associated with the interaction between artefacts and the environmental conditions (Doehene, 2010; Maravelaki, 1992; Bonazza, 2009) in the idea also to give some general guidelines. In general, the environment parameters to be monitored should be selected considering the chemical composition of the support and, as underlined in recent studies, the well known gaseous pollutants responsible of the degradation of most of the artefacts: CO_2, SO_2 (less indicative as degradation factor respect the past), O_3 (especially as indoor value), NOx, etc. (De la Fuente, 2011; Watt, 2009). It is however not easy to define in advance some general and absolute parameters that need to be monitored as often strongly related to the specific characteristics of the artefact, to the local environment conditions and also the use of the buildings. Moreover, the monitoring campaigns should not be limited to the artefact conservation state, but should be extended to the control over time of the effectiveness of the treatments including the control of the temperature (in association with the RH%), the rainfall (e.g. pH value, direct/indirect action) and moreover to the anthropogenic contribution (that is to say, the visitors).

A complete monitoring campaign might not always be applicable to all the architectonic surfaces due to many factors as: the time necessary for collecting reliable results; the cost of such monitoring campaign; the state of conservation of the artefact itself which sometimes requires urgent interventions, etc. In this frame, the definition of "general models" is very important even at local level and helps monitoring the artefact conservation state and planning when an intervention of restoration-conservation is needed. The selection of the more useful and representative parameters is therefore crucial for an effective monitoring and knowledge of the conservation state.

An emblematic example about the necessity to re-evaluate the contribution of the possible environment degradation parameters is the case of the Ghirlandina Tower in Modena (Italy) (Sandrolini, 2011). In a first step the SO_2, commonly indicated as one of the most important degradation factor in urban areas, was selected as the main degradation factor of the tower stone. The monitoring campaign pointed out that the impact of the SO_2 level, in relation to the RH% values, was very low, while the freeze-thaw cycles was recognized as the main cause of degradation.

Once the conservation state and the causes of degradation of the structure are defined, the attention is usually focused on the practical treatment. This moment often leads to the downfall of the monitoring of the artefact conditions as many people consider the monitoring campaign concluded by the intervention. The treatment indeed defines the "reference zero point" for the monitoring over time of the artefact conservation state (preventive conservation and sustainability of the intervention). In fact, while the monitoring of the artefact conservation state before the intervention defines the threshold alarm beyond which an intervention is needed, the monitoring after the intervention allows to evaluate the effectiveness of the intervention over time, aiming to target the future maintenance interventions and to contain the maintenance costs.

The approach to the importance of the monitoring is therefore an important educational aspect, as outlined also by the Euromed Heritage 4 Project "ELAICH" (Educational Linkage Approach In Cultural Heritage) and more specifically by the issues related to monitoring and maintenance (Biscontin, 2011).

2. THE MONITORING AFTER THE INTERVENTION: EVALUATE THE EFFICIENCY OF THE INTERVENTIONS AND PRODUCTS

For architectural stone surfaces, the restoration intervention is generally concluded with the application of polymer-based products (e.g. consolidant, protective products) with water-repellent characteristics. The efficiency of these treatments is usually based on the reduction of the water penetration and the increase of the cohesion of the structure. The selection of the products is based on data experimentally obtained on standard materials in accordance with national and international regulations and parameters. Common is also to undergo the treated samples to artificial ageing for estimating the duration over time of the treatments.

According to the current Italian Normative, the efficiency of a protective or a consolidant is evaluated in laboratory before and after the application on specimens based on the following parameters (Normal, 1985):

• Colour variations of the support
• Evaluation of the water capillary absorption coefficient
• Measurements of water absorption by total immersion
• Measurements of water absorption at low pressure
• Evaluation of the contact angle (wettability)
• Evaporation rate of water consumption
• Distribution of the product into the support (by porosimetric measures)
• Measurements of water vapour permeability

It is common, in particular when working on buildings of no great historic value, to select in advance only the more suitable products and the parameters above mentioned in relation to specific requirement and condition of the support. However, while many studies indicate the possible useful parameters for the selection and evaluation of the products efficiency (Ferreira, 2008; VV.AA., 2011), there are no clear indications about the "associated numeric value" out of which the product can be judged as partially or totally ineffective. Moreover, the product efficiency over time is often related to the methods used for the products application and to the specific environmental conditions (Normal, 1985). These parameters are in fact decided in the laboratory under standardised conditions which hardly correspond to the real conditions where the buildings are located.

3. PROPOSED CRITERIA FOR THE MONITORING OF THE INTERVENTIONS: THE PROTECTION OF STONE SURFACES

Considering the difficulties to define general criteria for the selection of the more suitable products, two parameters in particular have been proposed: the permeability to water vapour and the water absorption. The water vapour permeability is in fact associated to the "compatibility" between product and support, while the latter gives an estimation of the ability of the product to reduce the contact between water and support (Ferreira, 2008; Normal, 1993). A high reduction of water vapour permeability usually represents a negative property of the treatment, while a high reduction of water absorption represents a positive characteristic.

Considering the two parameters, it is possible to build an hypothetical diagram of the efficaciousness area for the protective products in terms of water vapour permeability vs water absorption (Figure 1).

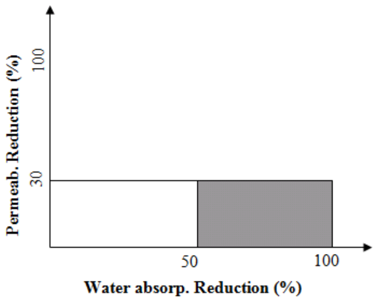

Figure 1: Hypothesis of the efficaciousness area for the protective products in terms of water vapour permeability and water absorption

Based on our previous experiences, the limit value for a good protection of the substrate will be equal to 50% for the water absorption by capillarity and 20% for the reduction in water vapour permeability taking into account also the compatibility between the systems product-stone.
There are some limitations in the choice of the permeability as indicative parameter of the efficiency of the treatment, because linked to the environmental conditions (RH% in particular) that is a difficult parameter to estimate outdoor. It means that the permeability, even if representative of the "compatibility" between support, consolidant-protective product and environment, cannot be selected as the only parameter for evaluating the efficiency of the treatment.

In this context, it becomes clear how important is to define significant parameters for evaluating the real efficiency of the interventions (Tsakalof, 2007). Moreover the monitoring of these parameters will give us an idea of the quality of the products over time. Figure 2 shows the most significant parameters and their relative importance ("weight") for evaluating the application of a protective coating on stones exposed to the external environment.

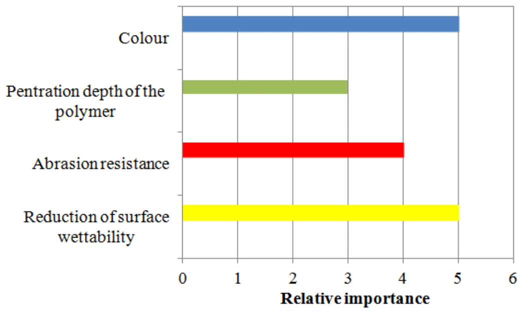

Figure 2: Most significant parameters and their relative importance ("weight") for an intervention of protection of stone exposed to the external environment

Based on Figure 2, the most important parameters for the selection and the monitoring of a protective intervention are: the surface final aspect (as chromatic change), the reduction of the material wettability and the surface abrasion resistance. The abrasion resistance is however playing a minor role. Its value is mainly linked to the mechanical action of rain and wind, but in times relatively long enough to be considered not relevant. The penetration of the polymer in the material has a high relevance in the case of consolidation, while it is less important in the case of the protection efficiency as the polymer penetration is limited mainly to the surface.

Nowadays, the colour variations of the materials before and after the product application are monitored at defined time intervals with portable spectrophotometers easy to use and able to provide *tristimulus* parameters (L*a*b*) (Nicoletti, 2001). Surface colour variations are commonly expressed in term of E and values below 3 are accepted as not appreciated by the human eye. Whenever this value is higher an intervention should be planned aiming to the elimination of the altered protective, when possible, and its replacement with a more a more stable and less invasive product.

The reduction of the water absorption by the stone surface after product application is generally estimated as a variation in term of absorption of water at low pressure (Biscontin, 1984). The system is of low cost, easy to use and can be done also in loco directly on the building. Alternative methods (e.g. use of sponges soaked in water) have been also proposed during the years but there are still doubts about the reliability of these methods and of the obtained results (Tiano, 2006).
As in the case of the colour variation, the success of the protective treatment must always be referred to the untreated material in term of decrease of water absorption coefficient. Moreover, the value of the untreated material would give the threshold limit below which the product can be considered ineffective and needs to be replaced. However, as this difference is strictly linked to the chemical-physical nature of the materials and the application time, it is necessary (as for the colour variation) to give an indicative standard procedure useful for evaluating when the product protection is compromised.

The quality of the product water protection could be expressed as a difference in percentage between the value at t_0 (measured just after the product application) and the value measurement after a fix time period. Whenever this value is higher than 50% the protection is compromised and the product must therefore be removed and replaced (Figure 3).

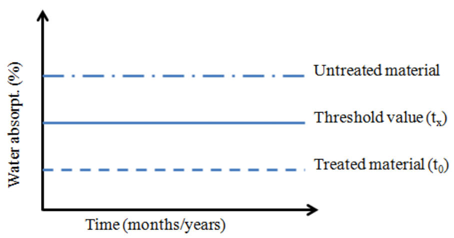

Figure 3: Threshold limits below which the product can be considered ineffective in terms of water absorption

The two proposed value for the colour variation and the water absorption might therefore be considered as threshold values for estimating the tangible protective efficiency of an intervention on stone surface.

The monitoring over time of the quality of the restoration is one of the most unclear topics. This operation is really important and must be designed case by case, as strictly connected to the chemical-physical characteristics of the support, the conditions of conservation, the use of the building (museum, church, etc.), the environmental conditions, etc. While there is a common agreement on the importance of the monitoring of the treatments over time, there are no existing guidelines on how this operation can be performed, which parameters can be used and more important how often. Recent publications (Vandevoordle, 2009) have shown that simple semi-annual inspections of selected areas can help in evaluating the efficiency of the protective coatings over time. The collected data give not only an estimation of the efficiency of the product but also a model of the possible product deterioration over time. In particular, variations of the surface colour changes and wettability offer some of the most interesting results because connected to the specific product requirements. Moreover, these parameters can easily be interpreted and measured at low cost, leading to the concepts of maintenance and sustainability.

A specific case study is the restoration of the Girlandina Tower (Modena, Italy) (Cadignani, 2012). Thanks to a maintenance and prevention project, the conditions of the materials and of the environment were monitored just after the interventions and over time for checking the effectiveness of the interventions. The collected data gave the possibility to evaluate, in real cases, the importance of the parameters selected for monitoring the conservation state of the surfaces and moreover their possible threshold values. In the case of the Girlandina Tower, the effectiveness of the protection treatment of the stone was evaluated based on the color variations (E) and the water absorption by low-pressure (pipette method).

Figure 4 shows the variation in colour, as E values, measured at different time over a balustrade in red Verona marble treated with an acrylic nano-emulsion. After 26 months from the treatment, the colour variations, as E, are still very small and below the perception value (E = 3).

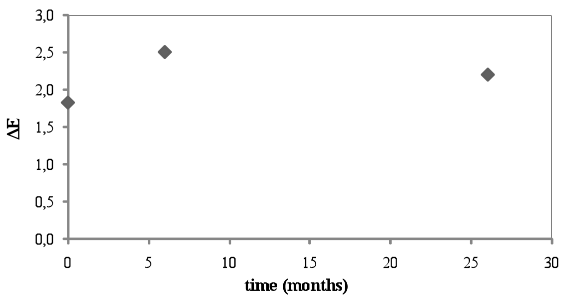

Figure 4: ΔE values versus time (months) of treated red Verona marble (Girlandina Tower, Modena)

After six months, the value of the water absorption at low pressure (Figure 5) indicates a modest reduction of the efficiency of the water-repellent product, compared to the value just after application. Regular monitoring of this parameter will allow specific intervention in the areas where this reduction is most significant, as those most prone to rain degradation.

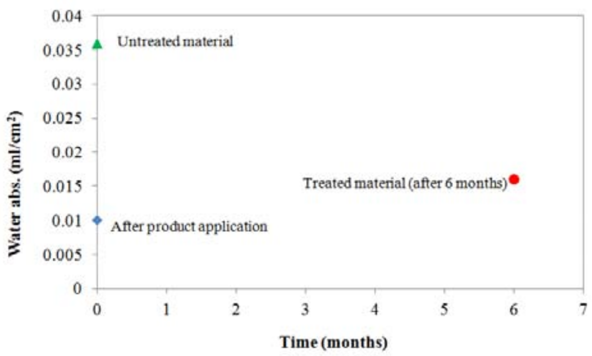

Figure 5: water absorption (as ml/cm^2) under low pressure methodology by the stone as untreated, just after application and after 6 months of product application

4. CONCLUDING REMARKS

The monitoring of architectural surfaces is complex and cannot be reduce to the simple monitoring of the conservation state (e.g. deposition of dust, formation of fissures, etc.). A complete monitoring intervention must include the control over time of the effectiveness of the interventions and of the products. This must lead to a possible maintenance plan aiming to a preventive conservation and to the reduction of the economic costs and, most important, cultural losses.

The obvious difficulty of establishing standard criteria for evaluating the effectiveness of conservative treatments can partly be overcome by defining specific parameters that need to be considered in relation to the expected product performances. In the case of the protection, a reduction of the surface water absorption (wettability) must be achieved without changing its final appearance (colour). The reduction of water absorption and the colour of the surface are parameters easy to measure and to monitor directly on the site even from not expertises. Combining the data collected in situ and in the laboratory, it will be possible to suggest threshold values for which the treatment can be considered effective. It is here proposed to set these thresholds values to variations equal to 3% E for the surface colour variations and to 50% for the reduction of water adsorption, compared to the values obtained just after application of the protective. The semi-annual or annual monitoring of these parameters will give an estimation of the effective quality of the treatments over time and will give the possibility to intervene before the stone material is compromised.

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COMPLEX COMPARATIVE TESTS ON HISTORIC STONE

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KEY WORDS: Stone mechanical characteristics, Physical characteristics, Lithotype, Water absorption, Micro drilling, Peeling test, Ultrasonics

ABSTRACT:

This paper presents an abbreviated review of the potential capacities of the project on Non-destructive and Considerately (Medium) Destructive Methods for Testing Historic Stone, developed within the 7th EC FP STONECORE project. These methods include ultrasonic tests, peeling tests, drilling resistance and water uptake by various approaches. The material characteristics acquired by means of these methods are compared with the characteristics measured by destructive standard tests, and the observed correlations are discussed.

1. INTRODUCTION

Within the STONECORE [1] project, supported under the 7th EC Framework Programme, several innovative techniques for investigating some characteristics of stone have been suggested and developed. This paper presents a brief comparison between the potential capacities of the non-destructive and considerately (medium) destructive diagnostic methods that have been developed, on the one hand, and standard testing methods, on the other. It should be pointed out that destructive tests for determining mechanical characteristics are used for calibrating and assessing non-destructive methods.

In the course of research work within the STONECORE project, some further techniques were tested, e.g. hardness measurements by means of sphere indentation, rebound hammer tests, sequential picture evaluation and ultrasound measurements in a depth profile. However, the sampling was limited and/or the results were not convincing enough to develop the methods more deeply, so they are not included in this report. The characteristics exhibited by some of the tested stones were quite significantly heterogeneous. This must be taken into account when the results of the correlation studies are examined.

2. TESTED MATERIALS AND TEST SPECIMENS

The comparative tests were carried out on rocks that were available in necessary quantities, and that were related to historic buildings. Studies were carried out on stone blocks taken from Charles Bridge in Prague and from the Church of St. Barbara in Kutná Hora during recent repairs.

The tests included the following materials: "opuka" marl stone - sound stone from a quarry; travertine limestone - sound stone from a quarry; quartz sandstone - sound stone from a quarry in the Ho ice region; arkose (sandstone) - stone from Charles Bridge; detrital limestone - stone extracted from the Church of St. Barbara in Kutná Hora; Nehvizdy sandstone - stone from Charles Bridge; and Pet ín sandstone - stone from Charles Bridge.

The initial shape and size of the test specimens was chosen in the form of beams according to the standard specifications for tests of mechanical characteristics. The basic specimen dimensions were therefore 50 mm 50 mm 300 mm. The dimensions of the specimens of Kutná Hora limestone were 50 mm 33 mm 200 mm, as only shorter beams were available there, and the cross section height-to-span ratio required for the bending tests was maintained. Five specimens (in exceptional cases three specimens) were prepared for each test.

3. TESTED CHARACTERISTICS AND TEST CONDITIONS

The destructive tests included determining the mechanical characteristics, namely strength in compression, strength in three-point bending (modulus of rupture), and the Young modulus of elasticity computed from the deflections measured during the bending tests. These tests require a sufficient volume of material to be extracted from existing buildings for preparing standard test specimens, and the tests are carried out in a laboratory.

Considerate destructive tests are intended for tests carried out *in situ*. They damage existing structures in a negligible manner from the aesthetic and also the static point of view. In this study tests of this kind were of drilling resistance, mercury porosimetry and microscopy on thin sections.

Other characteristics were measured using non-destructive methods, but for the sake of comparison some of them were applied in a way that cannot be used *in situ*. Thus the tests have some destructive features. Capillary water uptake and also ultrasonic measurements in the transition mode belong to the family of destructive tests, in terms of specimen preparation and application.

The only purely non-destructive tests here involve water absorption determined by means of the so-called Karsten tube and by new microtube measurements.

The test specimens were conditioned before the test in a climatic chamber (for standard tests in "dry conditions") at 70°C ± 5 °C till an equilibrium state of moisture content, which was

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measured by weighing at intervals of 24 ± 2 hours with accuracy of 0,1 g. In the equilibrium state the mass of the test specimen does not change by more than 0,1%. After drying and before testing, the test specimens are stored in an environment with a temperature of 20°C ± 5 °C until the temperature is balanced. The test was then carried out within 24 hours.

Two physical states were applied for the tests – dry conditions (as described above) and fully water-saturated conditions *(SN 72 1154),* in situations that were relevant for studying the characteristics of the materials (mechanical tests and ultrasonic tests). All the tests were carried out in the ITAM laboratories.

Petrography analysis (not described in the paper) followed the standard methodology (EN 12407) and local petrography tables were used. The structure of the samples and their mineralogical and petrographic composition were investigated in polarized microscopy (PPL in transmission polarized light, XPL for crossed prisms, RPL in reflected skew polarized light). Investigations of the basic matrix and cements in sandstone samples made use of SME and a CAMECA SX-100 microanalyser equipped with four crystal spectrometers (elements can be determined in the range from B to U), and with detectors of secondary and reflected (backscattered) electrons (BSE).

4. TESTING METHODS

The testing methods are briefly characterized, without details of the measured data that is used for comparison or for correlation studies, as described below.

4.1 Ultrasonic material characteristics

Ultrasonic tests were carried out on beams with dimensions of 50 50 300 mm using the UKS 12 device produced by Geotron Elektronik. UKS 12 comprises a generator of electric impulses, two transducers (one for transmission and one for receiving) and a microsecond timer. The timer has a screen where the received wave is shown, so that the time when the wave passes through the sample can be read. The frequency used for the measurements was 20 kHz, and the data was measured in the three main mutually perpendicular directions typical for layered stone, Figure 1.

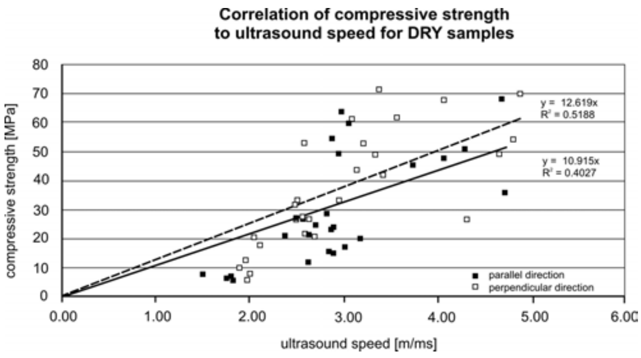

Figure 1. Correlation of compressive strength to ultrasound speed for dry samples.

4.2 Near surface cohesion characteristics of stone

A peeling test is used to determine the surface cohesion ("strength") of the material. It can be used for assessing surface degradation and/or for assessing improvements in surface properties after application of a consolidation agent. In the course of the test, adhesive strips are attached sequentially and then removed from the same place, and the weight of the removed material is determined by laboratory scales. The process model anticipates that some asymptotic value of the removed material will be reached by the end of the test (and denoted as A [g]). This value characterizes the surface strength, and should be related to the overall strength of the material, Figure 2.

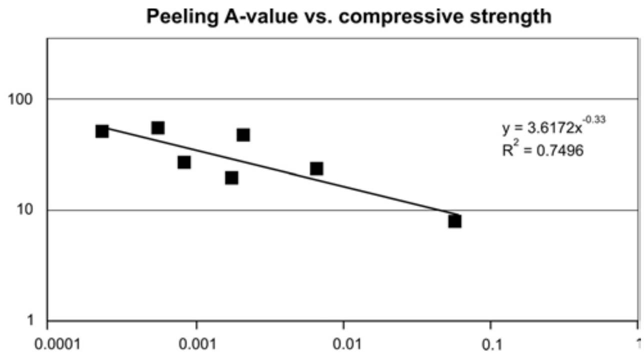

Figure 2. Correlation between the A-value [g] and the strength [MPa] of the tested material, showing indirect proportionality between the two properties.

The values of A should be indirectly proportional to the strength of the material. Lack of this correlation can be due attributed to several other factors, especially the fact that the material property called fracture toughness also comes into play. In relation to fracture toughness, the importance of the heterogeneity, porosity and strength of the interfaces between phases rises. The measurement procedure and a discussion of the influences on the measurement are presented in detail in (Drdáck et al. 2012b).

An approximation form

$$m(n) = A + B * e^{-C*n}$$

describing the sequence of weights of the removed material m(n) is also suggested in (Drdáck et al. 2012b).

4.3 Drilling resistance characteristics

Drilling resistance is usually expressed in terms of the time it takes the drill to penetrate to a certain depth at a defined pressure and speed of revolution. However, on the basis of empirical observations, it can be related to strength and hardness. Drilling resistance is usually used for making a comparison between the state of the material before and after an intervention, or the effectiveness of various treatments is compared by drilling under the same conditions. Drilling resistance is expressed e.g. in seconds per millimeter.

Drilling resistance depends on two process parameters: velocity, taken as the number of revolutions per unit time, and applied force, which determines the rate at which the drill penetrates the material. This means that the rate varies from material to material, reflecting the strength profile of the specimen. This is the approach embodied in the Tersis device, manufactured by Geotron Elektronik.

Due to its constant load, the Tersis drilling device is best suited for investigating the strength profiles of weak and soft materials, sensitively recording every detail, every minute obstruction in the path of the drill. Accordingly, high frequency of data acquisition is obtained: about 30 records per second, corresponding to approximately one hundred records per millimeter, based on the typical drilling speed and several thousand data points, assuming a typical hole depth of about three centimeters. However, the results have to be interpreted carefully, distinguishing different phases of the material influencing the drilling speed. In addition, drilling resistance does not yield any results above a certain strength of the tested material.

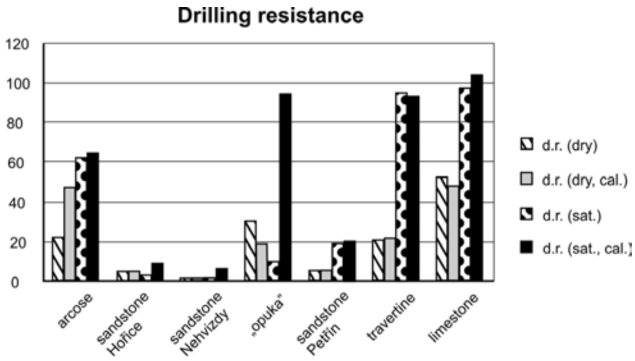

Figure 3. Summarized drilling resistance rates for the studied stones in dry and saturated condition.

The results presented in Figure 3 indicate strong influence of water on the drilling process, slowing down the process of removing the drilled material. Drill bits are worn away in the process of measuring drilling resistance. This causes an apparent change in the drilling resistance rate that has to be adjusted by calibration.

4.4 Water absorption characteristics

Three different methods have been used for determining water absorption. First, the absorption property was tested on beams 50 50 300 mm, and also on cubes 50 50 50 mm for all the materials. All the tests kept to the conditions set by Czech technical standard SN EN 1925: Natural stone test methods – Determination of water absorption coefficient by capillarity (a Czech version of European Standard EN 1925:1999).

The so-called Karsten tube has been used for several recent decades for *in situ* measurements, e.g. (Rapp et al. 1997). It was the second method for water absorption measurements. However, the application of this method *in situ* leads to some difficulties, which can be summarized as follows: i) problems with fixing a heavy glass tube on to vertical surfaces, ii) problems with sealing the contact ring area, iii) the need for two operators – one who observes the water movement in the measurement tube with a stop-watch, and another who records the readings, iv) soiling of the surface with sealing putty.

A pilot prototype of an innovated device was therefore developed within the project, and it is being further improved. The new system is based on a way of making continuous electronic measurements of water infusion into the surface. This enables long-term recording of the water sorption from the very beginning. The device consists of a scaled glass microtube in which the movement of the meniscus is watched, and crossing of the marks is recorded manually by a switch or in a container with a float connected to a movement sensor for automatic reading. The measurement reduces the number of operators, it is more precise, more effective and faster (Drdáck et al. 2011, Drdáck et al. 2012a). The device is presented in Figure 4, and the correlation of all three methods is shown in Figure 5.

Figure 4. Application of a microtube device for in situ measurement of mortar water absorption characteristics.

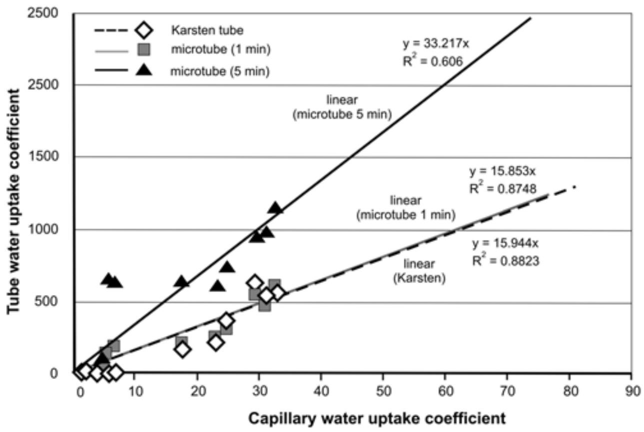

Figure 5. A comparison of water absorption characteristics measured by means of different methods.

5. SPECIFIC MASS AND POROSITY CHARACTERISTICS

Specific mass and also total and open porosity were determined on dry specimens after mechanical tests and/or on specimens intended for water-saturated mechanical tests before the destructive tests, according to the EN 1936 standard.

Mercury porosimetry was used for determining the porosity and the pore size distribution, i.e. the volumetric distribution of the open pores, which is assumed to have a circular cross section, according to their size (radius or diameter).

The stones under study are composed of elements of different atomic weight, but grouped into compounds, crystals and minerals of very similar density. Porosity is therefore a decisive factor determining the specific mass property. Due to this correlation, porosity can be assessed by specific mass measurement, see Figure 6.

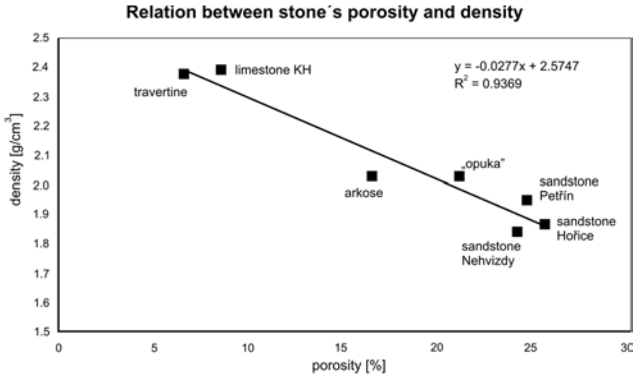

Figure 6. Relation between the porosity of the stone and its density.

6. TESTS OF MECHANICAL CHARACTERISTICS

Flexural strength in three-point bending was tested on beams 50 50 300 mm. All the tests kept to the conditions set by the Czech technical standard SN EN 12372: Natural stone test methods – Determination of flexural strength under concentrated load (a Czech version of European Standard EN 12372:2006).

Compression strength was tested on cubes 50 50 50 mm. The tested samples were sawn from undamaged parts of beams formerly used for flexural strength. All the tests kept to the conditions set by Czech technical standard SN EN 1926: Natural stone test methods – Determination of uniaxial compressive strength (a Czech version of European Standard EN 1926:2006).

Ten samples were tested for almost all of the stone materials and for each condition (dry, water-saturated), so the sets of results for statistical evaluation were relatively broad. Variation is a measure of the dispersion of the probability distribution, and can be taken as an indicator of the accuracy of the experiments. The accuracy for sets where the variation was below 0.20 was declared sufficient, and the final average value and standard deviation were calculated from the whole set. For sets where the variation exceeded 0.20, values outside an interval of one standard deviation were eliminated from the final statistical evaluation. In a few cases, the final variation exceeds 0.20, because further reduction of the value sets does not affect the results significantly. The acquired data was used for comparison or in correlation studies.

7. CONCLUSION – COMPARISON OF THE TESTED METHODS

The correlations between various characteristics not only provide information on the applicability of individual non-destructive methods but also indicate more profound dependencies and material qualities.

Naturally, the material density and the mechanical characteristics correlate. Because there is a fairly good correlation between porosity and bulk density, see Figure 6, a good correlation between porosity and mechanical characteristics is also expected, as confirmed in Figure 7. A relation between porosity and flexural strength is also a well documented fact.

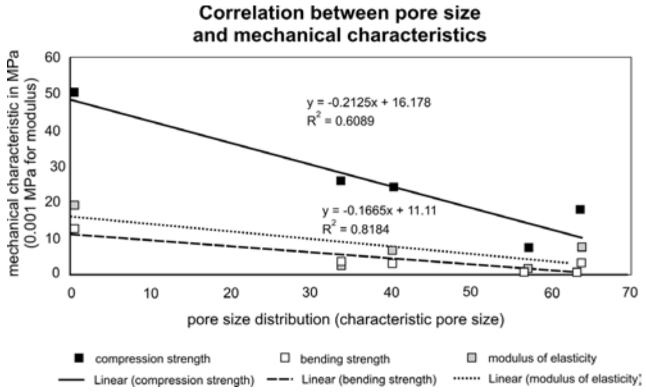

Figure 7. Correlation between pore size and mechanical properties.

In situ pore size measurement relies on the application of water uptake investigations. Our experiments proved, using various techniques, that there is a fairly good correlation between pore size characteristics and water absorption measurements, see Figure 8.

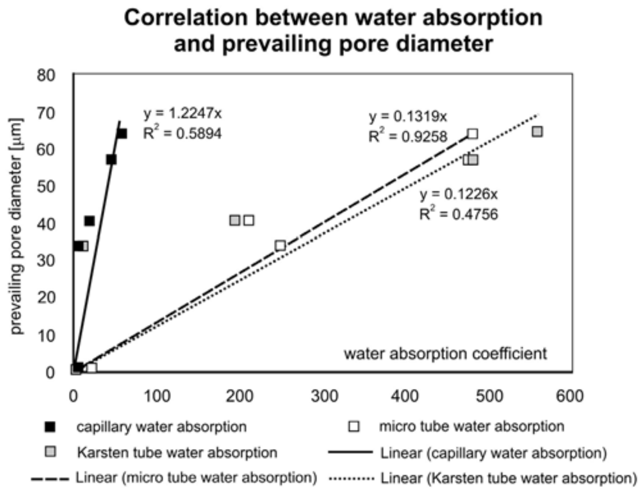

Figure 8. Correlation between water absorption, measured by means of various techniques, and the prevailing pore diameter.

Naturally, this also implies that mechanical characteristics can also be estimated via water uptake measurements. However, in practical situations the natural moisture content would make the method very difficult to apply, or it would be necessary to use special drying procedures and microtube measurements of the water uptake. For reasons of space, it is not possible to present the acquired data in greater detail and under various moisture conditions, which are very important in engineering practice.

The ability to assess values for the mechanical properties of stone that would otherwise be impossible to measure nondestructively is the main contribution of the comparative studies presented here.

The correlations presented here show that the development of new testing approaches for historic materials, namely when applied on site, has a significant potential and requires further research. The results achieved during the STONECORE project and our follow-up work indicate promising directions that are worth investigating and developing.

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LASER SCANNING AND INFRA-RED THERMOGRAPHIC PROSPECTING FOR DIAGNOSTIC MAPPING AND RESTORATION PROJECTS: THE CASE THE PAINTED TOMBS AT CYRENE (LIBYA)

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KEY WORDS: Diagnostic, 3D reconstructions, Infra-red thermo-camera, restoration, GIS, Laser Scanner.

ABSTRACT:

The team of Chieti University is involved in a GIS project of the monumental rupestrian necropolis of the Greco-Roman site of Cyrene (Libya). Because of the large number and of the monumentality of the tombs and of the rocky sanctuaries, the team is composed of a large number of scholars and technicians, including archaeologists, topographers, geologists, anthropologists, biologists, natural scientists, restorers and architects, working together and using different technologies, both for mapping and for projecting restoration and valorisation of these splendid but almost unknown monuments. In order to explain the methodologies and the technologies in use for this project, the Painted tombs of the northern and southern necropolis are presented in this paper, as examples of the technical protocols and of the multidisciplinary approach converging into a multilayer GIS project.

1. INTRODUCTION

1.1 The project: general issues

Cyrene has certainly one of the most spectacular and well preserved rocky necropolis of the Mediterranean Basin (Cassels 1955; Thorn 2005), but at the same time it is the least known by the scholars. The funerary area consists of myriads of tombs alternating with impressive rocky sanctuaries, which represent the most vivid example of mixture and integration between Greco-Roman and Libyan cultures, with a strong cultural and topographical impact on the local background, showing great example of rupestrian Greek architecture.

The vastness, the density and the monumentality of the whole area made necessary a systematic project of survey, excavation, GIS mapping (see Appendix below and fig.7) and documentation of this huge but neglected patrimony. The team from Chieti University started in 1999 (Fabbricotti 2006; Menozzi 2007, 2008, 2010) a project of surveying and mapping of the southern and eastern necropolis, giving birth to a GIS using DGPS and Robotic total station for positioning and recording the tombs and multispectral HD satellite images, previously hortho-rectified and geo-referred, combined with RADAR data for highly detailed topographic base, DEM and DTM. From 2004, the survey and the GIS have been extended also to the western and northern necropolis, counting at the moment about 1500 mapped and recorded tombs (see Appendix and fig.7). The project involves the use of field survey and excavation in combination with remote sensing on aerial and panchromatic satellite HD images, geological surveys and analysis, geo-archaeological non invasive prospecting (using mainly magnetometric methods), DGPS positioning, archaeometric analysis, constituting levels of an integrated multilayer GIS database working as collector of the huge amount of data (Cherstich, Fossataro, Menozzi 2010; Menozzi, Fossataro, 2010).

A natural consequence of the wide differentiation of scientific approaches is the use of a large team including in the project scholars and PhD students with very different backgrounds, provenances, attitudes and experiences. From the large amount of results it is now possible to create models of the evolution of the necropolis, looking to its landscape assessment, to its growth in combination with the urban context, to the development of the architectonical typologies of the tombs, in order to contextualize more properly, chronologically and topographically, the evolution of this monumental ‘city of the Dead’.

The GIS mapping of this large amount of funerary monuments and tombs, includes rocky chambers with architectonic Doric, Ionic and Aeolic porticoes and decorations, monumental *loculi* and sarcophagi, painted and inscribed tombs, funerary courtyards, tumuli, *mausolea* and mastabas, as well as rocky sanctuaries closely related with the funerary cults and the local Libyan culture. The GIS of Chieti University (Fig.7), which is carried out in collaboration with the local Department of Antiquities, is yearly updated with seasons of intensive field survey, specific excavations in sensible areas, remote sensing and geo-prospecting.

The huge amount of data coming from this project are at the moment stored in the Archive of the Archaeological Mission of Chieti University and in the Department of Antiquities of Cyrene, both containing not only the geo-database of the GIS project, in ArchView version (ShapeFile), but also photos, drawings and notes. However, our team is now projecting the possible publication on a Google Earth platform, with complete dataset in a remote version, and a lighter version of the geo-database in a public version. This further step could allow a wider use of the data and a larger possibility of project in collaboration among different institutions and teams working for common purposes.

This typology of innovative and multidisciplinary approach is particularly important at the moment for Cyrene, because of the strict need for this site to respect the new UNESCO parameters and protocols, asking to the local Department of Antiquities for new maps of the archaeological site, more detailed buffer zones delimitations and constant diagnostic mapping of the remains, especially after the recent conflict.

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In this sense the GIS project, in general, is certainly a great help for the local authorities, representing also a field for strict collaboration with them, and at the same time can offer to the UNESCO important tools for monitoring and controlling the developments and the urbanization in this site, which are among the main UNESCO objectives.
Moreover, the GIS, using basically ArcView (9.2 and 10.1) and QGis software, has been planned also for a simplified version using Goggle Earth protocols, in order to transfer more easily geo-referenced data both to the Departments of Antiquities in Libya, as well as to UNESCO offices or to other teams working in Libya, where other Italian, French, English, Polish, German and American Missions are working and could exchange data and information more easily through a common geo-database.

1.2 The Diagnostic mapping of the painted tombs: aims and methodologies

However, together with a topographic and architectonic approach of research, the team is also applying the most recent technologies for diagnostic reason, in order to have a clear situation also of the problems of preservation of these monuments, mapping, as a layer of the GIS, typologies of damage, risks, act of vandalisms, and possible suggestions for restoration and conservation for these monuments.
We intend to present here, as example of the methodologies and technologies used in this project, just the case of the monumental rupestrian painted tombs of Cyrene, from their mapping, digital high definition documentation, archaeological, geological and biological analysis, to the results and to the suggestions for projecting their conservation, restoration and valorisation.
The painted tombs represent a rare and precious group of funerary monuments in the northern and southern necropolis at Cyrene, and they are also particularly delicate, for their easy accessibility, constant frequentation, frequent aggression by natural agents, decay of the paintings and phenomena of vandalisms deteriorating frescoes and plaster, also considering the recent war event, which have not caused large damage inside the town of ancient Cyrene, but in its *chora* and necropolis have caused more problems.
From the methodological point of view the documentation of these tombs have been based on several steps, aiming a complete mapping and analysis of the damage, before planning interventions of conservation, restoration and future valorisation.
First of all the tombs have been scanned with a HD laser scanner, with two scanning for the external facade and per each internal side at a high definition, with a even higher definition for the painted and plastered areas. During this phase, the laser scanner, which has got its own internal photo-camera, has taken several photos of the internal and external views, in order to use the photos to give the natural appearance to the monument, thanks to the merging of the data in post processing. In this way the damage can be mapped both on reconstructive 3D models of the tombs, but also on 3D real reconstructions of the monuments with their own real appearance and with the possibility of a precise navigation within the model. Moreover, scanning the monuments every year can allow also to follow the development of the damage and the time of the decay of the paintings, monitoring in this way more systematically and constantly the monuments.
A second step has been the photogrammetric documentation with a high definition photo-camera, helping in the interpretation of the remains of the paintings, documenting with more detail also their smaller damage. In post processing, moreover, is has also been possible the merging of the high definition photogrammetric shots with the data of the laser scanner.
A following step in the protocol has been the analysis of the monuments with the infra-red photo camera, which has been fundamental to individuate the main wet areas, problems of humidity, micro-infiltrations and their consequences as lichens, *fungus*, *algae*, *cyanogen-bacteria* and detachments of plaster and paintings.
Moreover a further fundamental step has been the archaeometrical analysis of samples (including thin section and SEM analysis) of the paintings and of its plaster bases, in order to understand the composition and the micro-stratigraphy of the paintings and to plan more carefully the consolidation of the paintings.
A team of restorers have analysed our reports and documentation and verified the damage, suggesting the possible solutions case by case, integrating our detailed mapping of the damage with the solutions then proposed to the local Department of Antiquities.
A biologist has also surveyed the tombs, in order to make database and mapping of the biological micro-organisms deteriorating the paintings and the limestone. This has also been a very useful base for the conservative project.
However, one of the main problems of these tombs is also due to their total abandonment, to the not existing valorisation and safeguard, to their too easy accessibility without fences or limitative enclosure, exposing them every day to vandalism, to not proper frequentation, robbery, internal barbecues, which became even more problematic during the recent war, when this rocky funerary chambers were used as refuges. Therefore, a collaboration with architects, has made also possible a further step in our project, that is an hypothetic plan of valorisation and safeguard of these monuments, recuperating also their background, planning for tourist tracks and projecting possible solutions for using fences or enclosure to prevent future new damage after the restorations but with an impact to the natural and archaeological background as lowest as possible.

2. THE PAINTED TOMBS OF CYRENE

2.1 Tomb N 241: Tomb of the Good Shepherd (northern necropolis)

The so called 'Tomb of the good shepherd' (Bacchielli, 1990-91), consists in a rocky chamber tomb, with 4 inner monumental *arcosolia* on the lateral sides and a larger and central *arcosolium* on the main side, just in front of the entrance (Fig.1). The floor level of the tomb is lower than the external level and therefore a small staircase at the entrance gives access to the funerary chamber, emphasising the passage to the funerary room. The external façade is not particularly elaborated, it does not presents any architectonical decoration and shows a plain facade. The area just outside the tomb is characterised, as usual in Cyrenaican rocky tombs, by an external squared courtyard, creating a sort of sacred area devoted to the tomb, and delimited by remains of the original rocky slopes, which have been in antiquity cut and adapted and partially integrated by artificial sections of walls, to create a *temenos* of the funerary space.
Concerning the paintings, they are located on the *arcosolium* at the northern-eastern corner, and on the facade of the sarcophagus just below it. The iconography of the *arcosolium* presents a peacock standing on a *kantaros*, which are

surrounded and emphasised by garlands and fishes, with strong references to Christian symbolic representations. The front of the sarcophagus, just below this *arcosolium*, has represented a shepherd with its flock, and carrying one of the sheep on his shoulders, again with a strong Christian symbolism remanding to the well known iconography of the 'Good Shepherd'.

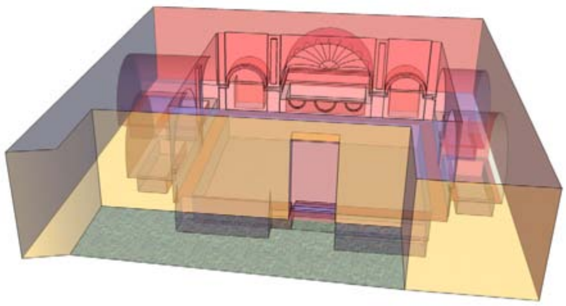

Figure 1: 3D model of the tomb

The monument shows several phases of use, with an earlier Hellenistic phase and later interventions. However last interventions, including the paintings have been dated to the end of the 4th-beginning of the 5th centuries AD.
The laser scanning of the tomb has allowed a precise volumetric documentation, giving the possibility of thematic plans, sections, prospects and drawings of details. The photos taken directly by the internal camera of the laser scanner (Fig.2) have been able to locate precisely the remains of the paintings, as well as the most evident problems affecting the tomb, such as lichens, modern writings, damage and so on. The photogrammetric documentation, then, undertaken with a high definition camera, after the post processing, allowed a better reading of even the smaller details, representing a great base for the mapping and analysis of the degradation and for the project of consolidation and restoration.

Figure 2: View from the laser scanning of the tomb

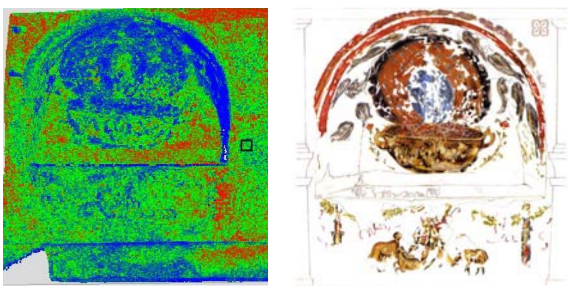

Figure 3: IR Thermography of the painted *arcosolium* (on the left) and reconstruction (on the right) of the paintings.

The infra-red analysis (Fig.3), which have been widely employed for this tomb, has been able to show many problematic areas, especially for the high concentration of humidity, such as along the western internal side, especially at the corners, as well as area exposed to the direct light which has caused the proliferation of invasive *heliophile* micro-organisms.
The problems therefore mapped for this tomb come from different origins. Most of the problems comes from humidity causing the proliferation of moss on the lower painted area. There is also some damage due to some modern writing, graffiti and drawings, mainly obliterating and in some case damaging the inner plastered, sculpted and painted surfaces. A greasy patina is covering the upper paintings and the inner sides of the rocky funerary chamber, mainly due to the dusty atmosphere in combination with occasional fires, because of the easily accessibility of the tomb therefore and used for picnic. A homogeneous level of white painting, probably done in the 40s of last century for reusing the tomb (which is quite frequent in Cyrene's necropolis) is covering most of the inner surfaces, stopping the proliferation of musk and likens, but covering other possible paintings. The presence of accumulations of soil and litter within the lower sarcophagus just below the painted area, is increasing the rise of condense for paintings and their plaster base is transmitting for capillarity even more quickly moisture and microorganisms.

2.2 Tomb N 22: Tomb of the Ludi (northern necropolis)

The paintings are very badly preserved, but presenting very interesting subjects, thematically homogeneous and running all around the four sides of a rectangular rocky funerary chamber, showing several typologies of ancient games, both gladiatorial, hunting, musical and athletic competitions, carriages racings, Greco-Roman wrestling (Fig.4). The paintings date to the Roman Imperial period (Bacchielli, 2002a; Bacchielli, 2002b).
The first step to document the tomb has been the photogrammetric documentation, which has been done both on dry and wet paintings.
Then the documentation has been compared with the old photos and drawings, in order to understand how much the damage are growing. The laser scanning in this case has not been possible because of the problematic light.

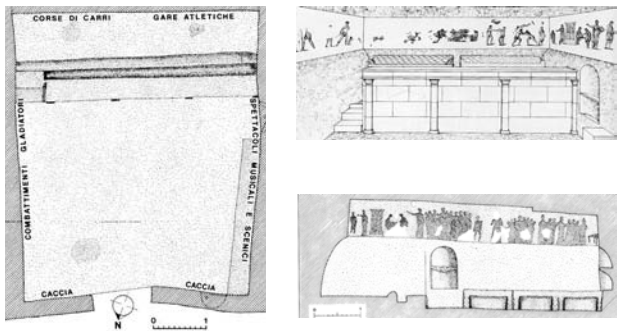

Figure 4: The tomb of the Ludi and the inner decorations

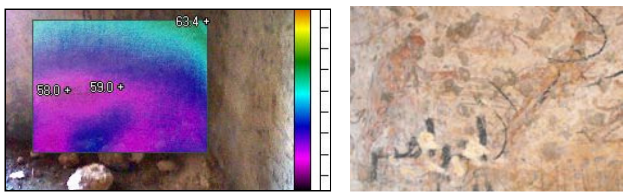

Figure 5: Infra-red thermographic shot: example of a humid area (on the left) and particular of the paintings (on the right) showing some of the problems affecting them

The problems presented by this tomb are mainly due to a lot of modern writing and graffiti on the paintings, on the walls and on the ceiling (Fig.5). Moreover, a greasy patina on the paintings and evident remains of firing and picnic are quite evident.
There is also a technical problem of the paintings, which is due to the use in antiquity of very diluted colours and of a very thin base of preparation, which makes even more difficult their preservation and caused already partially loose of some areas of the paintings. The concentration of moisture (Fig.5) in specific areas both for micro-infiltrations, capillarity and for rising humidity from below, generally due to the presence of accumulation of soil and rabbles, is causing the proliferation of micro-organisms in the lower sections of the walls and saline efflorescence in the upper part due to the typology of the local limestone, rich in mineral salts.

2.3 Tomb N 83: Tomb of Demetrìa (northern necropolis)

It is similar in plan to the so called Tomb of the Good Shepherd, consisting in a rocky chamber tomb (Fig.6), with a very simple façade, an external courtyard, and with *arcosolia* inside, covering burials in form of sarcophagi directly cut into the rocky bed. The *arcosolia* present shell decorations in three cases (the central one and the southern ones), a plain surface in the case of the north-eastern *arcosolium*, and a painted *arcosolium* in the north-western corner, as well as a painted inscription just at the left of the entrance, mentioning the owner of the tomb, *Demetrìa*, and her son, both dead during an earthquake, dating to the last decades of the 4th century AD (375) and dating then the paintings (Bacchielli, 1992).
The painted *arcosolium* (Fig.6) shows walls decorated with a polychrome grid pattern, reminding to the fences of a garden; while the ceiling presents a *paradeisos* scene, with flowers, different kinds of birds, peacocks and fishes below a male figure, suggesting again a strong Christian iconography.
The first step for documenting the monument has been the complete high definition laser scanning of the tomb which allowed a 3D mapping, which has then be used both as base for the diagnostic mapping and for 3D model and reconstruction of the tomb. The second step has been the photo-documentation directly taken, in this case, by the camera of the scanner, with photos which have been used to reinstitute the natural appearance to the interactive 3D models coming from the post processing of the data.

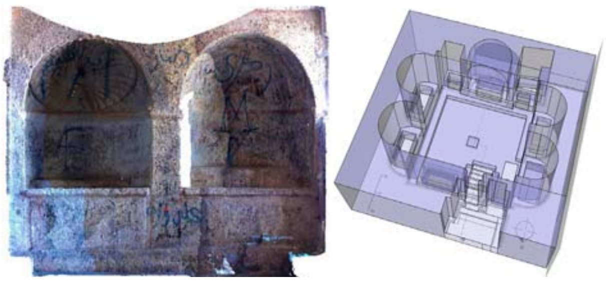

Figure 6: Laser scanning of the painted and decorated side and 3D model of the tomb

The third step has been the infra-red photo documentation, which has been able to show in a more detailed way the degree of the deterioration of the monument, including its areas with a high percentage of humidity.
Among the problems suffered by this monument, apart from modern writings and graffiti, there are areas with high quantity of mould and litter in the floor close to the lower part of the walls, particularly of the east wall, causing area of high density of humidity and micro-organisms. The tomb has been also the site of recent fires and the sarcophagus at the centre of the back wall is marked by signs of tea waste thrown there. There are numerous charcoal and spray paint writings.
The recent survey and documentation of the painting has allowed also to identify many new decorative details such as: the front cist imitating a garland sarcophagus and shows two different layers of plaster and paint; the case frame, which has a guilloche; the right pilaster, which has a guilloche and bands of red paint; the *arcosolium* conch with the *paradeisos* scene, and at least 4new birds and flowers can be identified.

2.4 Tomb N 173: Tomb of Ammonius the Veteran (northern necropolis)

The tomb consists of a funerary chamber with *loculi* burials and presents paintings on the walls and on the ceilings of the chamber. The monument is very badly preserved, both inside and outside. The charcoal drawings and writings strongly covering most of the paintings, but they can be easily removed, because they do not show incisions on the paintings. Some moisture is affecting the lower part of the funerary chamber, with higher concentrations in the corners, including the entrance and the bottoms of the *loculi*. The moisture seem to be thicker nearby the plaster and the old cement restorations. Encrustations for saline efflorescence, plaster detachment and rock calcification have damaged the wall presenting again a *paradeisos* scene (peacock, birds, vegetal and floral decoration) in the first panel. For the rest the paintings do not seem to have been too badly damaged. After a proper restoration this tomb could become one of the most important ones in the Northern Necropolis, with its wall-paintings, vivacious decorated ceiling with polychrome geometrical and floral patterns and funerary accoutrements.
The tomb has been documented with the infra-red thermo-camera, with photogrammetric survey and with remote sensing on post-processing of photos and thermo-camera shots. It has not been possible to use the laser scanner, because of the inaccessibility of this monument with delicate equipment. The documentation and photogrammetric reconstruction of the polychrome ceiling has been particularly difficult, but the high definition images and IR thermo-camera shots have been very useful for a detailed diagnostic analysis.

2.5 Tomb S 64: Tomb of the illusionistic architecture (southern necropolis)

The tomb S64 was already known as monumental rocky tomb with an antechamber and a funerary *loculus* chamber (Fig.7), but the paintings have been seen and identified just recently during the survey of our team (Cherstich, Santucci 2010). The tomb can be seen along the modern road linking ancient Cyrene to Balagrae, along a still well preserved track of the ancient Greek and Roman road. The front of the tomb hosts still part of the real architecture in course of ashlar masonry. The interior is organised in two sections. The first room is a rectangular antechamber with painted decorations, which acted as an introduction to the tomb, while the second room with its two series of double *loculi* hosted the burials. The sides of the external large squared courtyard host other rupestrian tombs and small niches for portrait busts, statues of the so called ‘funerary goddesses’ (so numerous and typical of Cyrenaican funerary uses and sculpture) and reliefs. The tomb is now used as a repository for agricultural tools. All the burials were looted in indefinite time periods. The tomb has been widely documented with graphic and photographic survey, macroscopic analysis of moulds and lichens; infrared and photogrammetric survey, drawings and graphic reconstruction of the walls. The infrared survey has been done at a constant distance of c. 1.3 m from the walls, because as also the light exposure and the temperature, the distance from the walls is one of the factors determining the good results of the data.

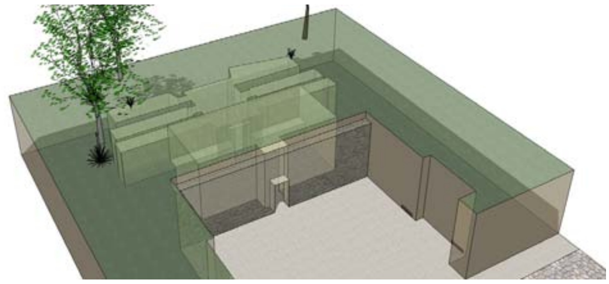

Figure 7: 3D model of the tomb with axonometric view

The problems presented by this tomb are quite similar to the previous ones. The wall of the first room are heavily covered by smoke signs. The wall paintings are damaged by charcoal graffiti and incised writings. Probably the soil above the tomb (which now hosts a vegetable garden) is not very thick and the irrigation water freely penetrate from above where the rock is collapsing. The wall-paintings are concentrated along all sides of the antechamber and they were used to integrate the benches and the architectures of this room, with illusionistic painted architectures, showing balusters, Doric porticoes and friezes, with portraits and statues among the columns, with an illusionistic perspective and the use of light yellow and red for the architectonic decorations and blue for creating chiaroscuro effects. The restoration, which is still in progress, will probably help in recovering many more elements.

3. CONCLUSIONS

3.1 Results and applications

The combination of different technologies, methodologies, scientific approaches is allowing, in the case of the painted tombs of Cyrene, as well as in general in the case of the necropolis of this site, a multilayer project focused on documenting the damage for a diagnostic step, on topographic and geological surveys for contextualise these rupestrian monuments, on the study of the iconographic apparatus, on the archaeometrical analysis. Moreover this large amount of data is now at the base of the project of conservation and valorisation, including also a plan for the safeguard of the monuments and a study of the impact on the local landscape of possible fences, enclosures and infrastructures for a sustainable tourist exploitation of the necropolis and its splendid monuments.
The innovative approach, including the use of DGPS, laser scanner techniques, non invasive geo-archaeological prospecting, Remote Sensing, Infra-Red documentation and Archaeometric analysis for diagnostic purpose is giving results in real time processing, accelerating enormously the process of mapping (especially comparing with traditional mapping as it has been done till recent times at Cyrene) with surveys not only focused on topographic matters, but also aiming diagnostic purposes and continuously monitoring the situation of the huge and monumental necropolis.
This protocol, which has been fully applied at the moment only to the necropolis of Cyrene, has also been adapted in an experimental way, to the study of the mosaics at Ptolemais, with similar purposes of diagnostic monitoring and valorisation project.

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3.4 Appendix: GIS of Cyrene

The GIS is organised in several levels, from a 'macro-GIS', showing the sites in a regional scale on wider Satellite bases (FC Zulu and Landscat), to the GIS of the site of Cyrene on HD Satellite Images. In this context, the figure below shows a general view of the GIS in progress of the monumental rupestrian necropolis of Cyrene on HD panchromatic Satellite image, with the location of the main tombs (dots), of the ancient urban area, and of the *temene* of the main ancient extramural sanctuaries. The painted tombs are indicated with their numbers and contextualised in their original locations.

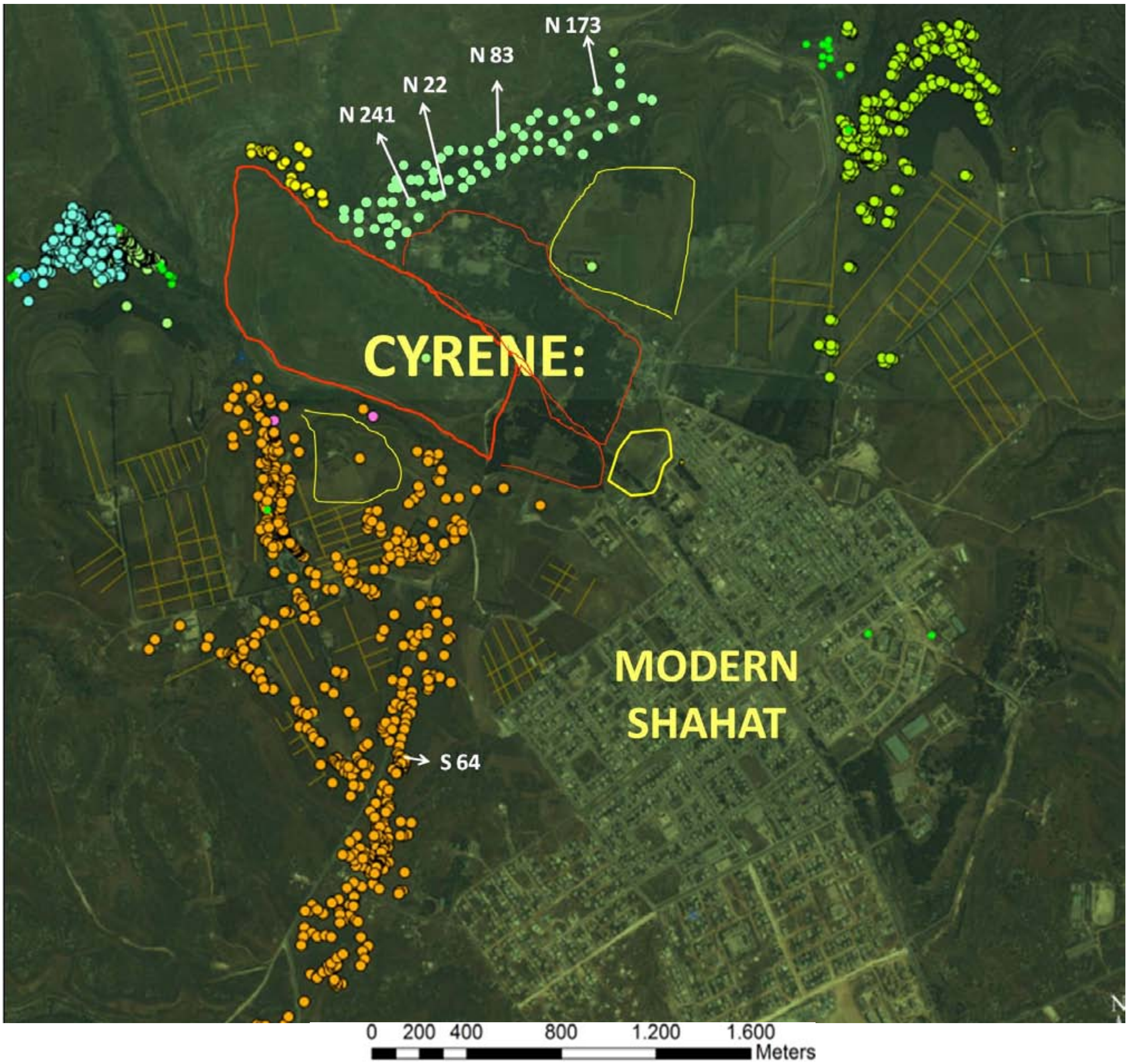

Figure 7: General view of the GIS of the territory of Cyrene, with its necropolis and extramural sanctuaries

EVALUATION OF THE ENVRIONMENTAL FEATURES OF VERNACULAR ARCHITECTURE. A CASE STUDY IN CYPRUS

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KEY WORDS: sustainability, thermal comfort, vernacular, bioclimatic

ABSTRACT:

Traditional settlements are by definition sustainable in relation to their environmental context and available resources. This paper investigates the environmental behaviour of vernacular architecture and the identification of the different factors that contribute to a pleasant environment and thermal comfort within traditional buildings and their surroundings. This investigation is part of an extended ongoing research programme which is the first research programme regarding the vernacular architecture of Cyprus that includes *in situ* measurements of temperature, humidity and ventilation using data loggers and weather stations. The results indicate the bioclimatic design elements of Cyprus' vernacular architecture and more specifically the passive strategies for heating (solar gains, thermal mass, thermal inertia), cooling (sun-shading, ventilation) and optimization of environmental microclimatic conditions (planting, evaporation). The analysis shows a relatively stable indoor temperature regardless of the fluctuation of outdoor temperature due to the considerable thermal mass of the structure. The data also indicates that the internal temperature reaches a maximum value later in the day compared with the external environment. This is related to the thermal inertia of the building's envelope that delays the heat transfer from the external environment to the internal space. Through this research the great significance of the internal courtyard was underlined, which serves as a microclimate regulator, keeping the temperature at higher levels than the external environment during the winter period. Taking into consideration the sustainability of vernacular architecture, the essential skills for environmentally-friendly approaches to the built environment can be developed, which will benefit society as a whole.

1. INTRODUCTION

Sustainable development is a priority for the building activities of many countries as these activities constitute an important part of energy consumption. In this framework the study of vernacular architecture can offer effective solutions towards the built environment being by definition sustainable in relation to its environmental context, using locally available resources to address local needs. Traditional settlements are well adapted to their surroundings (natural and social), respond to humans' actual needs, incorporate many features friendly to the environment (structure, forms, layout), and are thus considered as a model for sustainable design [1] and as a contribution to new methods and solutions for the future built environment [2]. As Rapoport [3,4] stresses, the form of a traditional house is defined by a series of socio-cultural factors and is shaped by climatic conditions, the available materials and the construction techniques. In addition, the rehabilitation of vernacular buildings constitutes by itself an important sustainable attitude towards the existing built environment as this incorporates the conservation of non-renewable sources.

Cyprus offers an excellent case for the study and analysis of the environmental features of vernacular architecture as it is a small island which incorporates many different types of dwellings and numerous features situated in different environments and climatic conditions. It has mountainous as well as plain and coastal areas with a variety in forms of dwellings in relation to date, layout, materials and construction methods. The typology often changes within a short distance in relation to the immediate environment depending also on the availability of materials [5,6].

In this paper we present the first analytical study to-date of environmental measurements of vernacular dwellings of Cyprus. The results of this study are part of an extended ongoing programme, the main objective of which is the overall investigation of environmental features of vernacular dwellings all over the island. Similar studies were carried out for the investigation of vernacular architecture of other countries of the Mediterranean Sea [7,8] and in other areas [9] but not in Cyprus.

1.1 The aims of the paper and the research

This research study aims to investigate the bioclimatic strategies followed in traditional dwellings and at the same time to assess the significance of conserving vernacular architecture. For this purpose *in situ* measurements and qualitative analysis of the behaviour of a characteristic traditional building in a rural semi-mountainous village of Cyprus in different seasons and weathering conditions were carried out - as a pilot case study. This will be followed by measurements in more vernacular structures in the same village and also in vernacular dwellings of other traditional settlements with a different geomorphology (mountainous areas, plains and cities).

The overall objective of this research is to produce new scientific knowledge, which will contribute to the sustainable development of the existing environment, "encouraging the sustainable use of resources and strengthening synergies between environmental protection and development" (National Reform Program for Lisbon).

This research aims at exploring and identifying the bioclimatic design principles and elements which have been applied, over time, in traditional architecture, in order to establish new ways of restoring traditional buildings, by focusing on maintaining and improving the above-mentioned principles. This research attempts to draft a set of guidelines and proposals for the proper conservation and restoration of traditional buildings, with emphasis on maintaining and enhancing the bioclimatic characteristics and environmentally-friendly approaches, through innovative solutions.

1.2 Analysis of bioclimatic elements of the vernacular architecture

Bioclimatic design refers to the incorporation of nature elements in architecture design, aiming at the improvement of comfort conditions – thermal, visual, acoustic comfort, indoor air quality – of the inhabitants of traditional buildings and the minimization of energy consumption. It is related to the application of a series of strategies in design and construction, which refer to passive heating and cooling, as well as to the improvement of microclimatic conditions of the surrounding environment and the exploitation of natural lighting.

The investigation of the different bioclimatic elements of vernacular architecture covers the exploration of the following features:

- Central courtyard (arrangement of closed and semi-open spaces around a central yard).
- Semi-open spaces / iliakoi (comfortable intermediate living spaces).
- Plants and water features in the courtyards (evaporating, cooling).
- Orientation of the house (arrangement of large openings towards the south for solar gains and small openings towards the north for minimizing thermal losses during winter).
- Traditional strategies for shading (roof overhangs, pergolas, plants, solid plank or adjustable shutters) and arrangement of semi-open spaces (iliakoi, porches, galleries) in front of the south side of the buildings [10,11].
- Traditional strategies for ventilation (multiple openings for cross ventilation, stack effect) and night cooling.
- Construction materials and quality of the building envelope (materials with thermal inertia such as mudbricks, stone walls and materials with thermal insulation properties such as successive layers of clay, twigs and straw for roofs).
- Relationship of buildings to their immediate built and natural environment (location in the urban core / nucleus, proximity to other buildings).

2. CASE STUDY

A systematic research was initiated to investigate the bioclimatic elements of the vernacular architecture of Cyprus and is concentrated on the semi-mountainous traditional settlement of Kapedes where specific measurements of temperature, relative humidity and air velocity were recorded.

In Kapedes, like most of the vernacular settlements of the island, locally available materials are used which reduce the energy consumption and the environmental impact, reinforcing at the same time the local characteristics of the settlement. The traditional rural architecture of the village is characterized by passive control elements such as stone walls with high thermal inertia and small windows representing the main elements of architectural expression. The traditional buildings are successfully integrated into their immediate environment being frequently arranged in compact patterns, closely built with common walls, one next to the other, leaving small empty spaces in the form of alleys and courtyards (Figure 1). Thus, the vertical surfaces (walls) exposed to solar radiation are reduced and the thermal inertia of the ensemble is raised. The shade between neighbouring buildings reduces the warming up of their walls by radiation and at the same time enables them to be cooled by contact with the cool air at night. Thus, nature, climate and topography are important parameters that play a significant role in the design. Streets are very narrow, surrounded by one or two-storey dwellings that offer shading to the passage way.

In order to have a more accurate qualitative and also quantitative assessment, a specific house that incorporates most of the above mentioned climatic characteristics was selected for investigation. The house consists of an iliakos, serving as an entrance and also as an intermediate space between the street and the house (Figures 2-4), a large double room (dichoro), a kitchen and some other small auxiliary rooms on the ground level and two bedrooms on the second level.

Figure 1. Aerial view of a part of the settlement

The load bearing structure of the house is built of internally-plastered masonry consisting of local stone and mudbricks. These walls are 50 cm thick at the ground level and about 40-45cm thick on the first floor level. The roof is made of timber, reeds and clay and is covered by tiles. The house has been conserved recently in its original form, preserving almost all its authentic characteristics. More specifically, the shell of the house has been conserved and only the roofs were repaired using insulation in the place of the original layers of earth and clay. All the openings were conserved and the original planks were replaced (Figure 4). A glass door was installed in the original arch opening of the iliakos so as to achieve internal circulation between the different rooms (Figures 5-6).

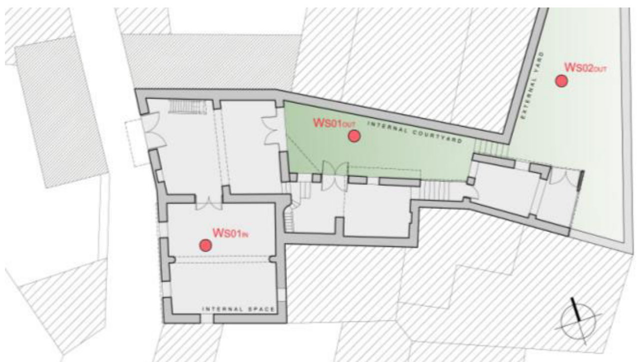


Figure 2. Plan of the house showing the measuring points (internal space, courtyard and external environment)

Figures 3-4. Internal view of the iliakos (Figure 3). The main entrance of the house (Figure 4).

2.1 Qualitative and quantitative evaluation of the house

The various rooms of the dwelling are arranged around a rather small central yard which constitutes a bioclimatic element of utmost importance (Figures 5-6). The small size of the courtyard operates as a microclimate regulator in the residence, assisting the integration of nature elements into the design and overall architectural concept of the building. The courtyard proportions and the arrangement of the rooms around it, especially the two-storey parts of the house, block the winds during winter and thus mitigate low temperatures. The small size of the courtyard is an excellent thermal regulator because its size helps towards the shading of the largest part of the walls during the day, allowing less thermal impact and more heat dissipation from adjoining indoor spaces. The whitish slabs of the courtyard as well as the surrounding walls act as a good radiator of heat and light penetration. Moreover, the courtyard ensures a pleasant view and visual comfort which contribute to the emotional and psychological condition of the occupants. According to Sullivan [12], "The courtyard integrates a wide variety of passive devices into its design, each creating its own thermal environment."

Figures 5-6. View of the house through the central courtyard before and after conservation.

Figures 7-8. West elevation of the house after conservation (Figure 7). The balcony above the main entrance of the house (Figure 8)

The iliakos, a semi-open space, in close relation with the yard, serves as an intermediate space between closed and open spaces and also as a buffer zone between the street and the courtyard, channelling breezes and improving the ventilation of the house.
In the traditional residence under study, sun protection is achieved through the use of appropriate sun shading elements on the openings. The traditional envelope incorporates a linear cantilever (balcony) on the front of the west openings (Figure 7-8). The thicknesses of the walls also ensure some shading of the openings. Moreover, the solid plank shutters of the openings provide shade and reduce the direct solar radiation (Figure 4). Several of the building's openings and part of the courtyard are sufficiently shaded from the surrounding built environment and the building itself (Figure 9). In addition, the sun protection elements contribute to the normalization and filtration of the natural lighting, which enters the interior space.
Ventilation is mainly achieved through the various openings of the house and especially through their cross arrangement (Figure 10). They are designed in size and placed proportionally in order to allow the required amount of light and air circulation and to provide comfort. Windows facing the exterior are minimized so as to be consistent with interior requirements. Small openings (arseres), specially placed on a high level, enable the hot air to escape to the outdoor environment during the cooling period and at the same time provide daylight to the maximum depth possible with minimum penetration of radiation and serve ventilation needs when the house is not occupied. The removal of hot air is also achieved through the staircase opening situated in the iliakos of the house (Figure 3). Most of the openings of the dwelling (seven) are arranged around the central yard underlying the importance of the yard with regard to the ventilation and cooling of individual rooms. Thus, the courtyard provides a unique opportunity of orientation of the house in relation to sunlight and ventilation and modifies the amount of sunlight entering the house, improving the microclimate.
Direct solar gains are the main strategy of bioclimatic design during the winter period. East, west and south-facing elevations benefit from the incoming solar energy through both the building envelope and the appropriate openings. The direct solar gains of the house seem to be rather limited due to the general layout of the house which was derived from the size and shape of the plot and the surrounding buildings.

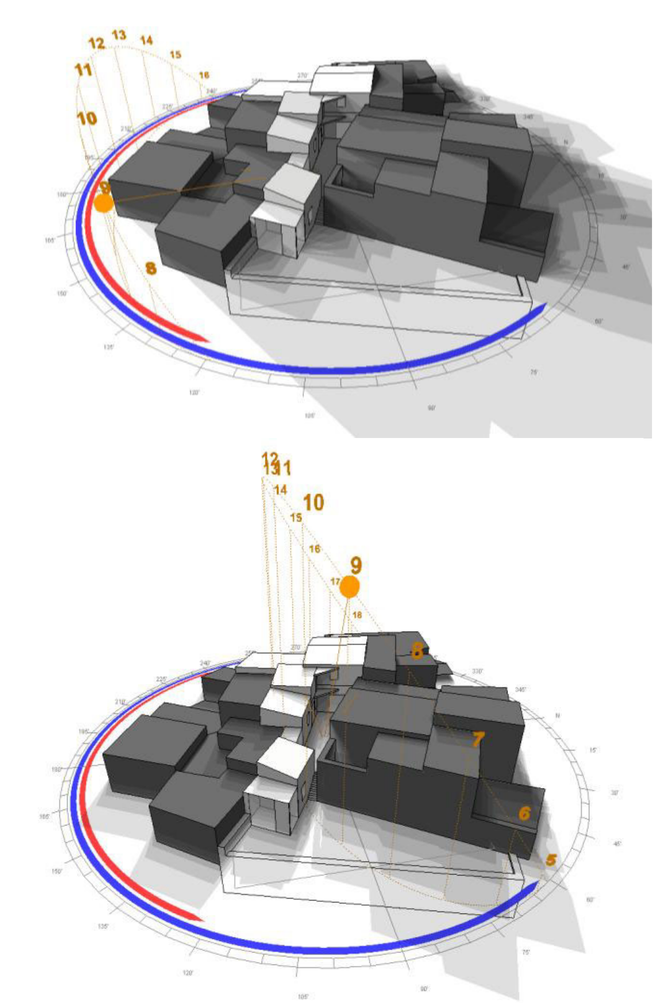


Figure 9. Simulation of shading range for winter and summer solstice (Ecotect software v.5.2).

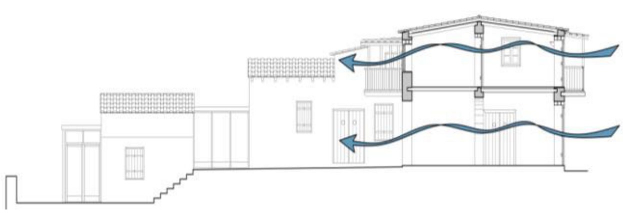


Figure 10. Traditional strategies for ventilation (cross ventilation and night cooling).

The application of proper materials (local stone, earth in the form of mudbricks, etc) and construction techniques (structure of roofs) ensure adequate thermal insulation and thermal inertia of the building envelope. The use of solid plank shutters in the openings prohibits the hot and cold air entering the house in summer and winter respectively.
The penetration of natural lighting is ensured through multiple openings in the building envelope. The distribution of natural lighting is also influenced by the configuration of the interior and the reflections of the surrounding surfaces within the building. Openings towards the courtyard provide visual connections as well as the possibility of physical connections with the external environment and nature.
Beyond the bioclimatic principals, the environmental approach of the traditional envelope refers to the selection of appropriate building materials to minimize the ecological footprint of the building. The reduction of the environmental damage, apart from the use of appropriate building materials (raw natural and local materials with low CO_2 emission and low embodied energy) refers to the use of appropriate building techniques (dry and assembled construction) and methods that allow re-use of the major part of construction materials of the building (recycled without downgrading the quality of materials).

2.2 Methodology

The quantitative analysis of this specific traditional residential building comprises the investigation and documentation of the applied design strategies for the improvement of microclimatic conditions. For the data acquisition, DAVIS Vantage Vue weather stations were placed for a period of six months in selected places of the residence under study (Figure 2). The measurements were conducted every 5 minutes from the 20th of December, 2011 until the 10th of June, 2012.
The registration equipment was placed in three selected places: (a) in the external yard for the registration of the external environment climatic data, (b) in the residence's central courtyard for the registration of the climatic data in the courtyard, and (c) in the most important internal space of the ground floor (dichoro), all measured at a height of 100 cm above the finished floor. The measurements of temperature and relative humidity refer both to the winter and the summer period. During both periods under study the residence was unoccupied having all of the openings closed, thus constantly eliminating all the internal heat gains.

2.1.1 Thermal Performance Analysis for the Winter Period:

The measurements of temperature and relative humidity for the time span of one week were analysed for the winter period (19th of February 2012, 00:00 hrs – 25th of February 2012, 24:00 hrs). The internal space has no technical support for heating. The measurements of temperature and relative humidity are presented in the graphs below (Figures 11, 12, 13).
The maximum temperature of the building's internal space for the winter period (19th of February 2012, 00:00 hrs - 25th of February 2012, 24:00 hrs) is 11.3 ºC, i.e. 2.6 ºC lower than the maximum temperature of the external environment. The respective temperature value of the climatic data in the courtyard during the same time period is 17.7 ºC, i.e. 3.8 ºC higher than the maximum temperature of the external environment. The minimum temperature of the building's internal space is 8.6 ºC, i.e. 8.0 ºC higher than the minimum temperature of the external environment.
The respective temperature value of the climatic data in the courtyard during the same time period is 1.7 ºC, i.e. 1.1 ºC higher than the minimum temperature of the external environment. The temperature fluctuation for the building's internal space is 2.7 ºC, 16.0 ºC for the courtyard and 13.3 ºC for the external environment. During the same time period, the mean temperature for the building's internal space is 10.2 ºC, i.e. 1.8 ºC higher than the mean temperature of the external environment and 2.9 ºC higher than the mean temperature of the climatic data in the courtyard (Figure 14). The comparison bars of relative humidity during the winter period are shown in the diagram below (Figure 15).

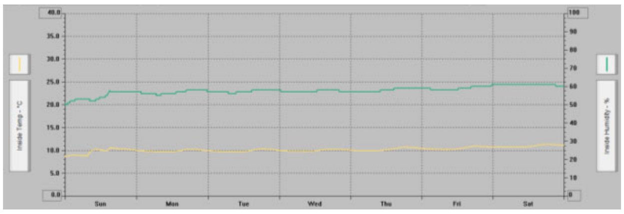


Figure 11. Temperature and Relative Humidity data of the building's internal space (dichoro) for the winter period (19th - 25th February, 2012).

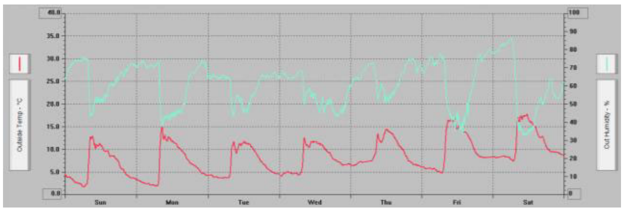


Figure 12. Temperature and Relative Humidity data of the courtyard for the winter period (19th - 25th February, 2012).

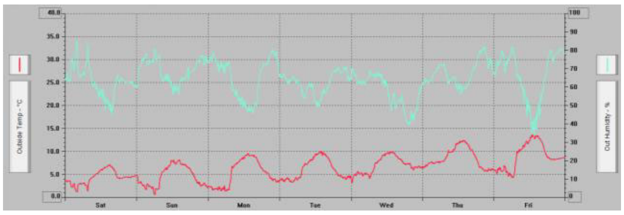
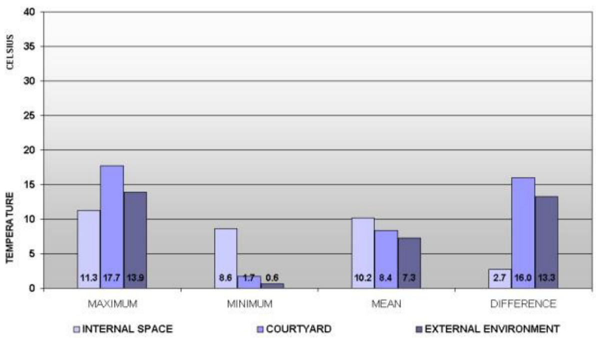
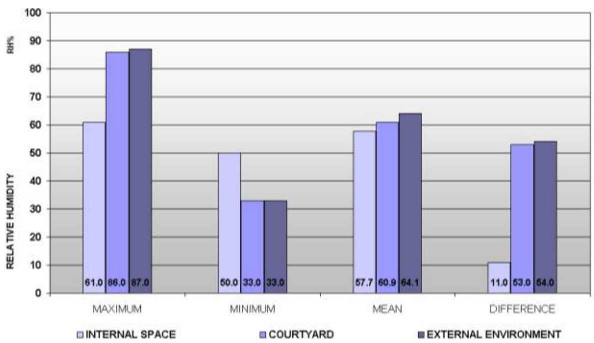


Figure 13. Temperature and Relative Humidity data of the external environment for the winter period (19th - 25th February, 2012).





Figures 14- 15. Comparison bars of temperature and relative humidity during the winter period (19th - 25th February, 2012).

2.1.2. Thermal Performance Analysis for the Summer Period: The measurements of temperature and relative humidity for the time span of one week were analysed for the summer period (3rd of June 2012, 00:00 hrs – 9th of June 2012, 24:00 hrs). The internal space has no technical support for cooling. The measurements of temperature and relative humidity are presented in the graphs that follow (Figures 16, 17, 18).

The maximum temperature of the building's internal space for the summer period (3rd of June 2012, 00:00 hrs - 9th of June 2012, 24:00 hrs) is 25.0 ºC, i.e. 6.9 ºC lower than the maximum temperature of the external environment. The respective temperature value of the climatic data in the courtyard during the same time period is 36.3 ºC, i.e. 4,4 ºC higher than the maximum temperature of the external environment. The minimum temperature of the building's internal space is 22.0 ºC, i.e. 5.7 ºC higher than the minimum temperature of the external environment. The respective temperature value of the climatic data in the courtyard during the same time period is 18.0 ºC, i.e. 1.7 ºC higher than the minimum temperature of the external environment.

The temperature fluctuation for the building's internal space is 3.0 ºC, 18.3 ºC for the courtyard and 15.6 ºC for the external environment. The mean temperature for the building's internal space, the external environment and the climatic data in the courtyard ranged at approximately the same levels, 23.5 ºC, 25.2 ºC and 23.3 ºC respectively (Figure 19). The comparison bars of relative humidity during the summer period are shown below (Figure 20).

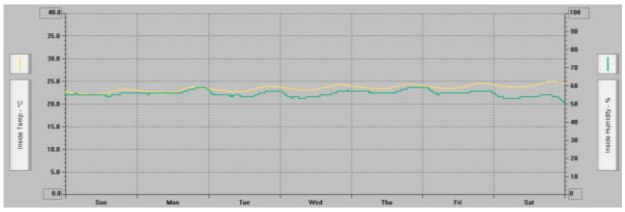


Figure 16. Temperature and Relative Humidity data of the building's internal space for the summer period (3rd - 9th June, 2012).

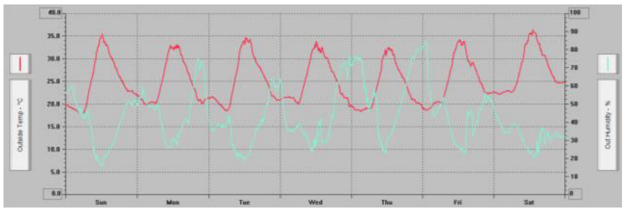


Figure 17. Temperature and Relative Humidity data of the central courtyard of the house for the summer period (3rd - 9th June, 2012).

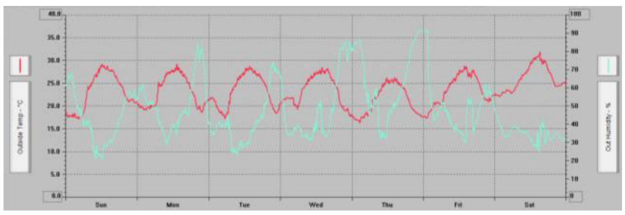
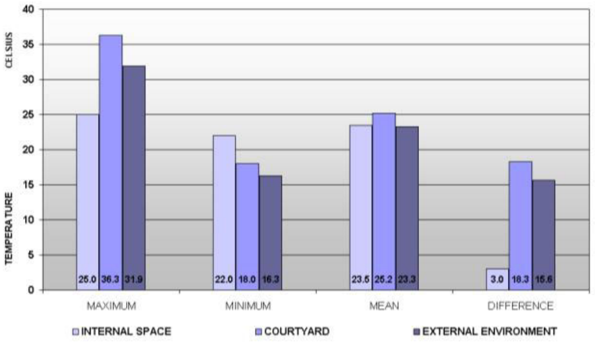
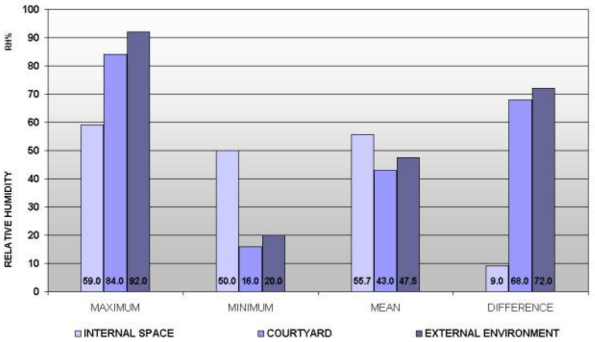


Figure 18. Temperature and Relative Humidity data of the external environment for the summer period (3rd - 9th June, 2012).





Figures 19- 20. Comparison bars of temperature and relative humidity during the summer period (3rd - 9th June, 2012).

3. CONCLUSIONS

The thermal performance analysis of the temperature and relative humidity for the above-mentioned periods provides for the first time in a scientific way, information on the thermal behaviour of a vernacular house in Cyprus. The analysis shows that the indoor temperature was relatively stable regardless of the fluctuation of outdoor temperature due to the considerable thermal mass of the structure. During the summer period, the indoor environment provides thermal comfort, although during the winter period the house's envelope fails to adequately retain heat at a comfortable level. The data shows that the internal temperature reaches a maximum value later in the day compared with the external environment. This is related to the fact that the thermal inertia of the building's envelope delays the heat transfer from the external environment to the internal space.

Through the study and *in situ* measurements of the temperature and humidity in a vernacular dwelling, the great significance of the internal courtyard was underlined, which serves as a microclimate regulator, keeping the temperature at higher levels than the external environment during the winter period. Although the courtyard is sufficiently shaded from the surrounding built environment, during the summer period an increase of the temperature in comparison to the external environment is recorded. This is due to the lack of proper planting in the courtyard as well as due to the closing of the iliakos's opening with a glass door prohibiting the cross ventilation of the house.

Thermal comfort in a traditional dwelling largely depends on the way the occupants make use of the house. The fact that the house under study was unoccupied during most of the period under investigation did not permit the application of solar gain strategies in the winter period and did not permit the application of cross ventilation and stack-effect strategies during the summer period.

Vernacular dwellings in Cyprus have adapted relatively well to climatic conditions by using low-energy design principles that ensure human comfort. The solutions followed were simple and easy to apply but at the same time they proved to be very efficient, showing a deep understanding of the adaptation to the surrounding environment. A systematic knowledge of traditional architecture and building technologies is the basis for supporting stable, balanced and sustainable socio-economic development and promoting conservation and rehabilitation of vernacular architecture. A deep and meaningful engagement with vernacular architecture and the rehabilitation process can inspire creative designs that sustain the productive life of the existing environment.

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A COMPARISON BETWEEN SYNTHETIC SPACE ANALYSIS AND INTANGIBLE HERITAGE INVESTIGATION IN URBAN CONSERVATION

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KEY WORDS: Space Structural Analysis, Space Syntax, Intangible Heritage, Urban Conservation, Mosul Old City, Urban renewal.

ABSTRACT:
The conservation of intangible heritage in historical regions has recently become a progressively important topic in the international level. Till recently, in the protection process of historical cities, the concentration has been on the tangible cultural heritage, built environment and historical buildings in old districts ;while safeguarding the intangible cultural heritage has been generally neglected. This paper aims at highlighting the significant role of the intangible heritage in the urban renewal policies of old historical districts. It undertakes the conservation and urban renewal activities of Mosul Old City (MOC) as a case study, and it explains that there are broad distinctions in various aspects between space structural analysis and intangible elements investigation, which designates that the intangible elements do not correlate to material or synthetic items within the urban fabric in the same high grade that is associated with the inhabitants memory of the historical area. It emphasizes the importance of the preservation of intangible heritage besides the tangible one in the urban renewal policies.

1. INTRODUCTION

In urban spaces, the cultural heritage of a community represents more than the aesthetic reminders of previous times, it inserts history into contemporary spaces then assists identifying the spirit and identity of a place. Yet, several histories or collective memories stay alive with physical traces. Due to gentrification, colonization, and exclusionary policies, various societies could not protect properties within their cities, consequently they left no physical remains to denote their memories of the sites where their histories took place. A number of cultural features of communities are presented in other modes such as stories, historical events and cultural activities which are relegated to cultural organizations leading to be incoherent from their environment and losing their importance to share and affect the urban public live. Currently, in the core of old cities, utilizing historic constructions as a variety of facilities including markets, workshops, shops, causes original residents to leave the area, consequently Genius Loci or the spirit of place is neglected. Thus, the historical areas are much more like stages, what to be conserved was just limited to the appearance but not the soul. The imbalance , in fact, reflects the weakness in our system, which, being exclusively concerned with protecting the tangible heritage overlooks the intangible heritage and thus leaves out great many cultural features that are essentially fundamental (Wang, 2008).

2. RESEARCH PROBLEM AND OBJECTIVE

Different circumstances in urban renewal projects of historic cities have varied physical, social, and spiritual notions that may produce various imperceptible values which might not be distinguished in a thorough analysis. Therefore, understanding and appreciating the significance of the essence of the urban context and its hidden values, including its spirit, requires an objective assessment and decisions for its conservation and management. The consideration and protection of intangible heritage in a historic city is a difficult issue due to the fact that such a character is mostly formed within tangible features.

The research main question is : do the results of space structural analysis correspond entirely with those achieved from intangible elements investigations, and if not, do the differences have negative impact on the decision-making in the urban renewal policies of the old cities?

The research aims to seriously examine how city heritage planning may contain insufficiently represented histories and intangible heritage through participatory procedures, and to improve a set of recommendations for a more comprehensive heritage preservation and urban renewal approaches. It looks at possibilities to enhance articulating tangible and intangible heritages collectively, in urban spaces; especially, by investigating how intangible heritage can help living history in such spaces.

3. SPACE STRUCTURAL ANALYSIS

3.1. Space Syntax Analysis

An array of theories and techniques for the analysis of spatial configurations are included in the term Space Syntax. Originally it was conceived by Bill Hillier, Julienne Hanson and colleagues at The Bartlett, University in the late 1970s to early 1980s as a tool to help architects simulate the likely social effects of their designs (Hillier,1984). Space Syntax is an important component for planners because it deals with topologically derived configuration and has techniques that allow the environment to be considered as independent variables. Primarily, Syntax is a method of investigating spatial complexes in an attempt to identify its particular structure that resides at the level of the entire configuration. The method is based upon the theory that the form-function relation in buildings and cities passes through the structural properties of its configuration (Hillier,1998).
Space syntax began from the observation that space is the common ground of the physical and social cities. The physical city is a complex pattern of space, while all social activities happen in space. In itself, of course, this leads to an impasse. All social activities leave spatial traces in the form of recursive patterns, but how can these relate to a physical context whose

essential patterns were in all likelihood laid down long ago, under the influence of quite different social circumstances? On reflection, the radically different rate of change of the physical and social cities seems in itself to forbid anything but a contingent relation between the two (Hillier, 1998).

The general idea is that spaces can be broken down into components, analyzed as networks of choices, then represented as maps and graphs that describe the relative connectivity and integration of those spaces (Hillier,1984). Over the past two decades, space syntax has been proposed as a new computational language to describe spatial patterns of modern cities. Using space syntax principles, human displacement patterns in the city can be analyzed, mainly by considering the degree to which urban spaces are integrated and connected. Many empirical studies have demonstrated the importance of space syntax for the modeling and understanding of urban patterns and structures(Jiang and Claramunt,2002).

According to (Hillier and Penn,2004) and (Ratti,2004) the general Space Syntax analysis techniques of a street network are Integration, Choice and Depth Distance. Integration (as used in this paper) determines how many turns one has to make from a street segment to reach all other street segments in the network, using shortest paths. If the amount of turns required for reaching all segments in the graph is analyzed, then the analysis is said to measure integration at radius 'n'. The first intersecting segment requires only one turn, the second two turns and so on. The street segments that require the least amount of turns to reach all other streets are called 'most integrate'.

4. INTANGIBLE HERITAGE

Intangible culture is to historic areas what the soul is to human being, therefore the UNESCO organization defined Intangible Heritage as non-physical heritage, which includes oral traditions, memories, languages, traditional crafts, performing arts or rituals, knowledge systems, values and know-how (UNESCO, 2003). For preservation purposes, sites are typically identified as physical morphological structures, consisting of frameworks and elements (Markeviciene, 2008). The Quebec Declaration states that ‘Heritage is a broad concept and includes the natural as well as the cultural environment. It encompasses landscapes, historic places, sites and built environments, as well as biodiversity, collections, past and continuing cultural practices, knowledge and living experiences’ (The Quebec Declaration, 2008).

Heritage conservation cannot substitute sustenance of traditional habitats, but it plays a crucial role in safeguarding tangible heritage and this way becomes a cradle for emerging future traditions (Markeviciene, 2008). The determinant character of a historic area can assert itself as its intangible value which is the spirit of it. Any tangible culture must be supported by intangible value and any intangible culture must rely on the tangible to be visualized. In virtue of the intangible heritage, the historic area will be full of energy, when intangible cultural heritage is carefully conserved, the tangible culture is accordingly conserved. Historic areas are gradually formed because of inhabitant’s life. So ,only by keeping and improving the living of the habitants there can the historic areas be conserved effectively (Wang, 2008).

Safeguarding measures to ensure that intangible cultural heritage can be transmitted from one generation to another are considerably different from those required for protecting tangible heritage (natural and cultural). However, some elements of tangible heritage are often associated with intangible cultural heritage. That is why the Convention includes, in its definition of intangible cultural heritage, the instruments, objects, artifacts and cultural spaces associated with it (UNESCO, 2003).

4.1. History of Intangible Heritage Preservation

The 16th General Assembly of the ICOMOS (International Council on Monuments and Sites), and more specifically the Youth Forum, the Aboriginal Forum and the Scientific Symposium, have provided an opportunity to further explore the relationship between tangible and intangible heritage, and the internal social and cultural mechanisms of the spirit of place. Spirit of place is defined as the tangible (Buildings, Sites, Landscapes, Routes, Objects) and the intangible elements (Memories, Narratives, Written Documents, Rituals, Festivals, Traditional Knowledge, Values, Textures, Colors, Odors, etc.), that is to say the physical and the spiritual elements that give meaning, value, emotion and mystery to place.

According to Norberg Schulz, the genius loci is the spirit or essence that gives life to people and animates place. In his book, genius loci is described as representing the sense people have of a place, understood as the sum of all physical as well as symbolic values in nature and the human environment” (Jiven and Larkham, 2003).

By its distinctive character the place is formed through time, creating the base of both a building and its users. Nevertheless, buildings are constructed out of the “spirit” of place, enhancing the meaning of the place, acting in harmony to produce urban spaces. In this perspective, human beings are responsible for giving “spirit” to place through their touches and their logical experiences between the buildings and the place (Nezih and Güçan,2008). The genius loci is defined, connected, and perpetuated by the memories and cultural meanings embedded in place. Tuan maintains that a sense of place goes beyond aesthetic appreciation – in other words , places are not always comfortable or welcoming (Davis,2007). Returning to R. Nezih the “spirit of place” refers to the understanding of the physical, social, economic, functional and spiritual relations between the three constant parameters, namely circumscriptions-lots and ownership, place and inhabitants” (Nezih and Güçan, 2008).

4.2. Genius Loci as an Intangible Heritage

Although Genius Loci has been defined by various disciplines, it is a vague phenomenological concept. The conceptual approach to the meaning of spirit of place emphasizes that it is created through history in a particular place of a town or a city, and requires an individual method of approach in conservation activities (Nezih and Güçan, 2008).

Genius Loci as a term was born in the Nile valley during the Pre-Dynastic period. Lacking the sophistication of modern science, Egyptians characterized the forces of nature as gods. In Roman mythology a genius loci was the protective spirit of a place. This has often been historically envisaged as a guardian animal or a small supernatural being. With the dawn of rationalism, this spiritual meaning of a place has been more and more negated. The modern movement in architecture tried to analyse the site based on scientific parameters and their optimization like sun angles and circulation distances. The fast growth of cities in the last century, which is still continuing today, and the application of the ,'modern formula' quickly resulted in sterile and faceless neighborhoods. First social problems resulted in high-density poor city quarters, but in fact, the fast growth of the single family houses in the agglomeration also result in places with no identity. The genius loci, which was found in medieval and renaissance cities has been lost! (Vogler and Vittori, 2006).

After the 2002 International Network of Cultural Policy meeting in Cape Town, South Africa and Senegal drafted a report on instruments to safeguard intangible heritage (Deacon et al, 2004). Three relevant findings include giving attention to “traditional and indigenous knowledge”, providing communities with economic incentives ideally other than selling cultural commodities, and seeing communities as “mode of creation and transmission of intangible heritage” (Deacon et al, 2004). The report suggests that communities need to be able to protect their intellectual property and improve or retain their socio-economic status (Leung, 2004).

5. TYPES OF INTANGIBLE HERITAGE

Intangible heritage essentially has several characteristics to be preserved under the Convention of the UNISCO including being transmitted from generation to generation; being constantly recreated by communities and groups, in response to their environment, interaction with nature, and history; providing communities and groups with a sense of identity and continuity; promoting respect for cultural diversity and human creativity; being compatible with international human rights instruments; and complying with the requirements of mutual respect among communities, and of sustainable development (Legislative Council Secretariat, 2009).

Intangible cultural heritage takes many forms: The Convention explains that it may be expressed in a number of domains, including but not limited to: a. Oral traditions and expressions including language as a vehicle of the intangible cultural heritage; b. Performing arts; c. Social practices, rituals and festive events; d. Knowledge and practice about nature and the universe; e. Traditional craftsmanship including (a) folk literature; (b) folk music; (c) folk dance; (d) traditional drama; (e) quyi or storytelling performances; (f) acrobatics and athletics; (g) folk art; (h) handicraft skills; (i) traditional medicine; and (j) folk customs (minsu) (UNESCO, 2003).

5.1. Methods of Analysis for the Intangible Heritage

As indicated by R. Nezih (Nezih and Güçan,2008) ,there are different methods used in the analysis of urban forms, grouped as methods of urban morphological analyses, architectural and urban design analyses, and urban conservation analyses.

Typo-morphological studies have been used as a design tool throughout history. They deal with the physical and spatial structure of the built environment and are derived from studies of typical spaces and city structures, based on detailed classifications of buildings and open spaces by type “typology”. They consider not only the various scales of the built environment, but also characterize the urban form with its inhabitants. As Moudon states, “typo-morphology offers a working definition of space and building type, and serves as a rich launching ground for studying the nature of building design, its relationship to the city, and to the society in which it takes place”.
Although these Typo-morphological tools are used rapidly in urban studies ,there is a big conflict because of the shortage of such tools in measuring intangible elements. Many studies used social questionnaires or inhabitance interviews to collect data from site during pre-survey phase. The pre-survey includes a comprehensive literature review, during which all graphic, historical, verbal and written documents related to the various aspects of the site are gathered. Then, base maps of various scales and survey sheets related to the buildings and social groups are prepared for the collection of data during the field work. Hence, the maps and data sheets assist in gathering the required information on the general characteristics of the site which will provide a foundation for the subsequent stages.

6. THE IMPORTANCE OF THE INTANGIBLE HERITAGE

Eliade points out, that in all cultures, places have had a deeply mythological meaning. The foundation of a house, a settlement or a town has been a religious act, which is still reminiscence today. Architecture has an eminent role as a key interface and definition of our being-in-the-world. Where natural environment is more and more lost, architecture takes a key role in creating places and in the best case a ‘genius loci’ (Vogler and Vittori, 2006).

The spirit of place offers a more comprehensive understanding of the living and, at the same time, permanent character of monuments, sites and cultural landscapes. It provides a richer, more dynamic, and inclusive vision of cultural heritage. Spirit of place exists, in one form or another, in practically all the cultures of the world, and is constructed by human beings in response to their social needs. The communities that inhabit place, especially when they are traditional societies, should be intimately associated in the safeguarding of its memory, vitality, continuity and spirituality (The Quebec Declaration, 2008).

7. THE PRACTICAL FRAMEWORK

The importance of the intangible heritage represented by its elements is recognized, hence, for the research purpose, it is vital to define its main aspects that are included in the concerned area, in order to clarify the impact of the Genius Loci on the developing planning of the urban historic fabric. Therefore, a review on the theoretical study demonstrates these elements as:

Memories and Commemorations;
Legend and Narrative;
Accident, Festival and Ritual;
Traditional Knowledge, Name and Occupation; and,
Value, Texture, Colure and Odor

7.1. The Case Study: Mosul Old City

In the (MOC) in Iraq, urban tradition is greatly presented as demonstrated by the traditional alleys, houses doorways, the old heritage public buildings, the "Quntara" (covering of the ancient alleys), "Shanasheel" (the upper parts in the traditional houses which are carried by the Kabools), the ornamental elements decorating many interior facades of the heritage houses, as well as many of archaeological components of Assyrian civilization and the ancient city of Nineveh.

For testing the theoretical framework, a part of the historic fabric of (MOC) has been selected, (Fig.1). The case study has been elected due to the variety of its building types and their cultural value; land use; and alleys geometric properties and characteristics. It includes several heritage houses of one of the famous families in Mosul with their supplement services, a number of public buildings like heritage public baths and schools, some significant religious building like mosques and churches, and few valuable urban features like alley arches.

In order to recognize the impact of the intangible elements on planning the urban renewal, two procedures have been carried out to derive results for comparison; the space syntax analysis method and the investigations of intangible heritage elements.

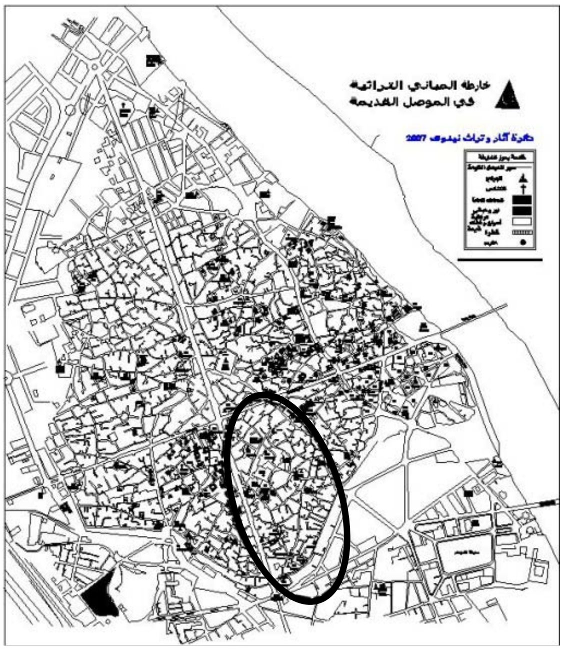

Fig.1: Mosul old city (source: Directorate of Antiquities)

7.2.1. Space Syntax Analysis

The first results obtained by the performed techniques are the outcomes of the calculation of space syntax method of the entire concerned site alleys, so as to recognize and identify the high integrated spots of the physical built heritage of the historic fabric. All segments have been numerated, given an identified number and listed in space syntax software with their relations with other fragments, and the calculating command was executed to compute the final results, which determined the integration level of entire alleys of the area. The results show the arrangement of the segments due to their integrity starting by the less value concluding by the higher ones. These values have been inserted on their related alleys in the concerned area map as illustrated in (Fig.2).

7.2.2. Intangible heritage investigation

Conversely, for distinguishing the intangible heritage elements and their values, a semi-structured questionnaire (including interview) has been distributed to (140) persons of the area residents and (10) specialists academic lecturers to define, characterize and classify available intangible elements in the related area.

The questions concentrate on two kinds of information. The first type is to mention the significant Memories, Commemoration, Legend, Narrative, Accident, Festival, Ritual, Traditional knowledge, Name, Occupation, Value, Texture, Colure and Odor characteristics of the area; while the second is to draw the image of accessibility by describing how specific known buildings in the core of the area could be accessed from surrounding main streets.

It was noted that there were a number of site related features have been frequented in the answers of the participants. A table of these elements and their frequencies has been created (Table.1) to demonstrate the important ones and to use them in the comparison process. In addition , a map for the locations of these features with series numbers has been indicated and their frequencies have been drawn in order to illustrate their concentrated spots (Fig.3). Each of these features has been mentioned in correlation with one or more intangible elements in the participants answers.

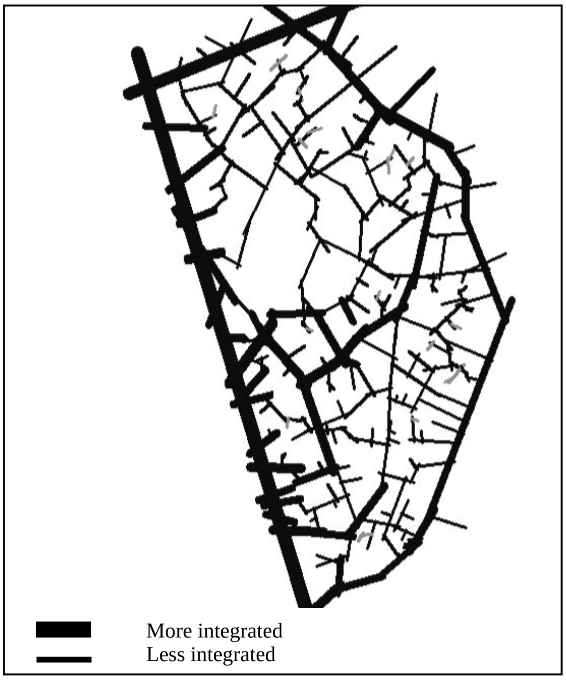

Fig.2: Results of the Space syntax analysis – The level of integration

No	Freq	No.	Freq	No.	Freq
1	10	18	42	35	105
2	11	19	92	36	22
3	10	20	93	37	103
4	51	21	23	38	52
5	221	22	21	39	33
6	92	23	10	40	142
7	63	24	112	41	10
8	133	25	12	42	116
9	34	26	132	43	63
10	31	27	183	44	262
11	62	28	62	45	96
12	32	29	85	46	145
13	10	30	64	47	34
14	94	31	52	48	82
15	40	32	25	49	14
16	30	33	83		
17	41	34	102		

Table.1: The mentioned features and their frequency

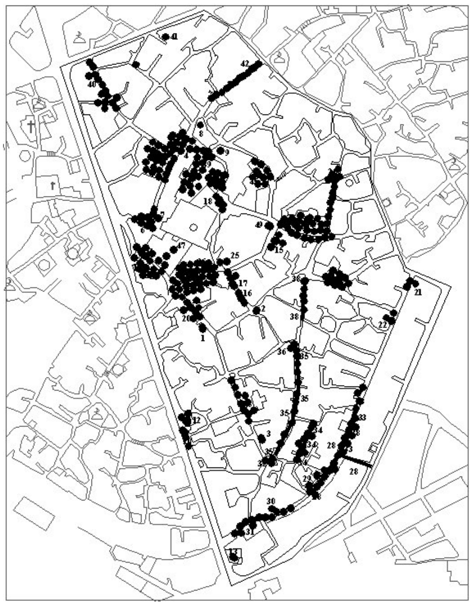

Fig. 3: Illustration of the concentrated spots of the intangible features

	No. 44	No. 5	No. 27	No. 24	No. 35	No. 34
Route Name / Character	**Al-Imam Own**	**Al-Alrabeea**	**Obaid Agha**	**Al-Thalath Blalee**	**Al-Barodjea**	**Al-Qamel**
Memorie, Commemoration	**104**	**96**	**17**	**-**	**6**	**5**
Legend, Narrative	**28**	**-**	**148**	**108**	**5**	**-**
Accident, Festival, Ritual,	**112**	**105**	**-**	**-**	**6**	**-**
Traditional Knowledge, Name, Occupation	**18**	**20**	**15**	**-**	**88**	**-**
Value, Texture, Colure, Odor	**-**	**-**	**3**	**4**	**-**	**97**
Frequency	**262**	**221**	**183**	**112**	**105**	**102**

Table. 2: Sample of the most intangible elements mentioned in the investigation related to allays

8. DISCUSSION

By calculating the space syntax analysis, and abstracting the questionnaires data, it can be noticed that:

For the space syntax analysis, there are several routes of high value of integration, in general, those have links with the outer main streets, with few alleys in the core of the concerned area as shown, and, normally, the integrated level gradually reduces when the alleys are more close to the central part. In contrary, for the intangible elements analysis, as frequented features mentioned by the interviewees, in different parts of the case study area, there are high concentration spots(Table.2) distributed accordantly as follows:

Memories and Commemorations link to public historical events, e.g. (Persian failed attempt to occupy Mosul - Althalma alley, No.33 has been frequented by 83 participants), or to the most famous person and his tomb (Al-Imam Own, No.44 has been frequented by 262 participants).

Legend and Narrative link to public baths, e.g. (fairies appearing, No.27 has been frequented by 183 participants), and arches of alleys, e.g. (night closure No.6 has been frequented by 92 participants).

Accident, Festival and Ritual, link to religion construction and spaces, e.g. (Alrabeea alley, No.5 has been frequented 221 participants, Imam Own Alley No.44 has been frequented by 262 participants, Alomaria district No.30 has been frequented by 64 participants,).

Traditional Knowledge, Name and Occupation link to human skills, e.g. (Barodjea alley - an alley of small traditional industry of gunpowder, No.35 has been frequented by 105 participants) or as a result of house location of a famous person in the alley (Al-Hamzawia alley, No.38 has been frequented by 52 participants) or for unusual case (Thalath balalee alley–three water channels of three alleys meet in an underground well, No.24 has been frequented by 112 participants).

Value, Texture, Colore and Odor link to an alley has a name due to a specific case, e.g. (Al-Qamel (Lice) alley due to its narrow width and it was so dirty at the past, No.34 has been frequented by 102 participants).

9. CONCLUSIONS, RECOMMENDATIONS AND INNOVATIONS

Comparing the final results (Table.3) proves that there are wide differences in many aspects between intangible features analysis and space syntax analysis, which indicates that, within the urban fabric, those intangible elements do not relate to physical or synthetic objects in the same high degree that is related to the sub-community's memory of the inhabitants and users (Fig. 4).

I.H. Route No.	**I.H. Order / 49**	I.H. Investigations Frequency	S.S. No.	S.S. Integration Order / 279	**S. S. Integration Order Average**
No. 44	**1st / 49**	262 times	146 147	69th 92nd	**80.5 /279**
No. 5	**2nd / 49**	221 times	82 83	153rd 167th	**160 / 279**
No.27	**3rd / 49**	183 times	163 164 169	47th 31st 6th	**28 / 279**
No. 24	**4th / 49**	112 times	141 20	39th 61st	**50 / 279**
No.35	**5th / 49**	105 times	244 254 239	66th 78th 40th	**61.3 / 279**
No. 34	**6th / 49**	102 times	248	149th	**149 / 279**

Table. 3: A comparison between Intangible Heritage Investigations and Space Syntax Analysis for sample of alleys

The final results highlight the impossibility of adoption of information derived from physical analysis in the process of developing renewal strategies for the historic cities in isolation of the sub-community contribution in the decision- making on such processes.

Planner awareness for urban intangible aspects plays a vital role in safeguarding any historic fabric, since such an environment has an implicit structured characteristics created by social commensality on various periods and, subsequently, the memory of the sub-community that lives within, thus it cannot be ignored or neglected in any urban renewal processes for these sites.

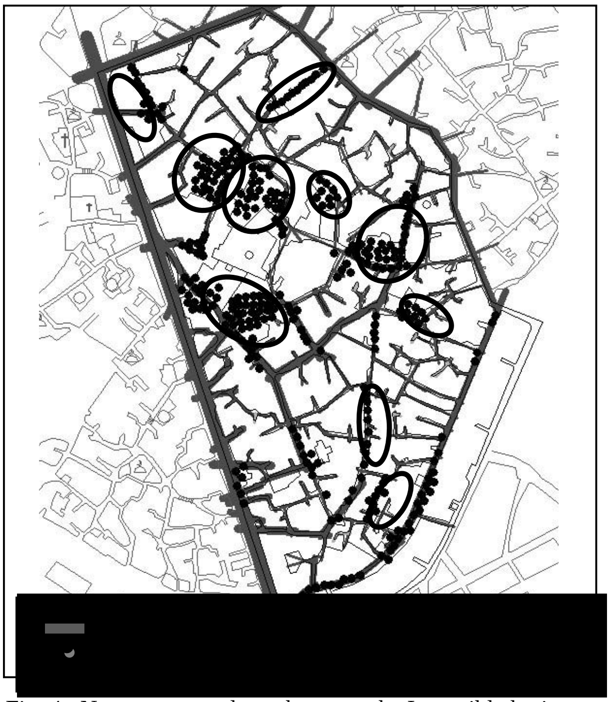
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Fig. 4 : Non-correspondence between the Intangible heritage elements and Space syntax analysis

In the historic urban fabric, despite the deep relations among tangible and intangible heritage elements in the residents memory, it does not mean that the intangible ones cannot establish individual memorial structure for its sub-community in a way that it will exist with the destruction of related physical building or alleys.

In most cases, there is a correlation between intangible inhabitants' memory and the built heritage, consequently, any insufficient decision or negative intervention for such features leads to destabilize and threaten these aspects in the memory. Hence, the urban renewal plan should pay attention to this correlation by encouraging and enforcing the useful and essential ones.

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REDISCOVERY OF THE COURTYARD, AS A MAJOR INTANGIBLE CULTURAL HERITAGE

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KEY WORDS: rediscovery of tradition, courtyards, intangible cultural heritage, spatial typologies, flexible courtyard, system of courtyards

ABSTRACT:

The radical and huge scale changes in the island of Cyprus, especially of the last century, resulted in a significant disruption with the social and cultural heritage. The paper will focus on the Courtyards as an indispensable part of the intangible cultural heritage which carries invaluable 'wisdoms' stemming out form the rich history of the island, the climatic and topographical conditions, but decapitated due to the modernization brought by the British colonization and the well rooted enforcement of the urban regulations of the young government. More specifically it will concentrate on ways and mechanisms of not only how to revive this intangible architectural quality, but rather to evolve it in order to generate new spatial typologies responding to the social and cultural changes in relation to their new organizational and functional requirements.

1 THE COURTYARD: CULTURE'S WISDOM FORGED THROUGH THE RICH HISTORY

The wisdom of traditional architecture in small, less-advanced places like Cyprus may be expressed by its organisation around a courtyard (Papacharalambous, 2001; Pfeifer, 2008). This architectural development took shape down the centuries (Sinos 1986), relating to and reflecting the specific climatic and socio-economic conditions, the activities and culture of a particular community (Lee, 1991; Khattab, 2001) and the levels of privacy and safety required, all of which were always subject to the external conditions brought about by different historical moments. (Danilo, 1997)

The various stages in the development of this 'core' element of Cypriot architecture are, of course, interrelated with the relevant technology, materiality and achievements of society. They can depict the level of development of its civilization and highlight the specificities of each historical period.

Due to its strategic location - as the confluence of the three continents of Europe, Asia and Africa – Cyprus attracted a series of invaders that conquered and occupied the island (Kyrris, 1996). In the last 2,000 years, Cyprus was under permanent occupation by successive kingdoms, empires and cultures, such as the Romans, Byzantines, the Francs, the Venetians and the Ottomans. Cyprus only gained its independence from British rule in 1960. Each conqueror left his mark on the traditional architecture of the island and consequently on the typology of the courtyard. (Schaar, 1995; Leventis, 2005)

Apparently, the British influence was the most radical and significant that formed the current built environment: it helped to modernise the planning of the island's settlements. On the other hand, these changes forced the traditional architectural element of the courtyard, and the way buildings were arranged around it, into extinction. It not only stifled any sort of development or evolution of traditional architecture but it abruptly disrupted the continuity from tradition to contemporary urbanscape. (Lee, 1991; Khattab, 2001; Li, 2010)

Unfortunately, these new regulations implemented by the British were adopted by the young Republic of Cyprus, and they are still in force. As a result, the merits of traditional wisdom were lost, and the new planning system, together with modernisation, brought about new typologies and spatial conditions largely irrelevant to the local climatic, cultural and social circumstances.

Rediscovery of the courtyards, through evolving instead of repeating

The current paper focuses on the notion of the courtyard, but without aiming simply to revive and reinterpret it: it attempts, rather, to focus on its evolution in a way that corresponds to the reestablishment of certain strong, still vital social characteristics of the island, while also responding to the new ways of living dictated by contemporary needs.

New approaches of the courtyard as the generator of innovative spatial conditions will be examined in this paper through a series of projects executed on the island of Cyprus by the author's architectural practice, ranging from an intervention on an already existing traditional house to a series of newly proposed, different typologies of housing projects, each in a different context.

Emphasis will be given on some characteristics that are considered important for the evolution of the courtyard organisations:

. The flexibility of the courtyard, and the achievement of diverse spatial conditions in order to respond to the ever changing social needs

. The issue of the blurring zones focussing on the thresholds such as the relationship between the in and out, private and public, old and new

. The materiality and technology, and the scale of their implementation

. The merits of the 'oasis' milieu of the courtyard deriving from the physical measures taken for enhancing the bioclimatic behaviour

. The scale and various possibilities of the evolution of the courtyard system, oscillating from generating interior design approach to an urban scale implementation in horizontal and vertical developments

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2 STARTING FROM THE ORIGIN: AN ATTEMPT TO RECUPERATE A TRADITIONAL COURTYARD HOUSE LITERALLY CUT IN THE MIDDLE

A Way to Heal the Amputation of a Traditional Spatial Organisation

An essential extension of a ‘truncated’ traditional house regenerates the amputated original ‘milieu’. The study refers to one half of a traditional house in Kaimakli, the result of dowry arrangements concerning the family property, which practically cut the house into two parts. The space that had suffered most, and which used to hold the spatial relationships of the house tightly together, acting in every way as the core of the original house, was the courtyard. What was left of it failed to maintain its inherent role as the main compositional architectural element of the house.

This ‘trauma’ in the original traditional courtyard typology of the house inspired the challenge for a radical approach: Not just to ‘fix the wounds but to ‘recuperate’ the traditional house and ‘convert’ it into a contemporary living unit through a new typology of a system of courtyards.

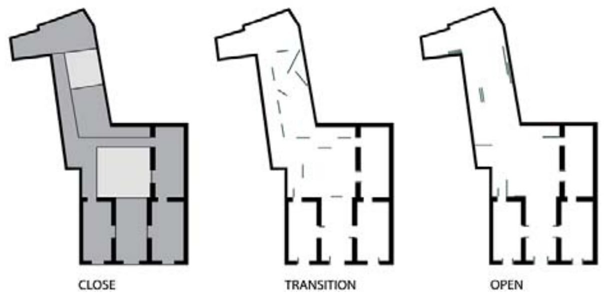

Figure 1: the three main stages of the new malleable courtyards in the traditional house

Transformation of the ‘remnant’ of the original courtyard into a “system of courtyards”: (fig.1) This system justifies its title through the qualities given to the courtyards themselves and to their practical interaction with the surrounding spaces that define them. As a first step, the remnant of the original courtyard was transformed into two smaller courtyards that facilitate the organisation of all the spaces and the circulation of the house. This spatial composition could by itself have been an adequate intervention to this specific house. Though, a further step was taken that addressed the new courtyards in a more holistic way, in an attempt to respond to a series of new, real needs in contemporary living. The new courtyards act together as a system in conjunction with the rest of the house, which is able to transform itself into an unexpected variety of spatial conditions, ultimately unifying the whole house into one multi-layered courtyard. (Tarkofsky, 1986)

Blurring zones: The original courtyard house had distinct physical borders of the indoor and outdoor spaces with the in between condition of the outdoor covered space, the so called ‘sun room’. Through this adopted courtyard system, the mechanism of ‘movable’ surfaces that substitute the walls, doors and separation elements constantly transforms the internal and, consequently, the external spaces, mingles or merges the public and private areas, alters the movements and pauses, interchanges openness with closeness, until finally it completely ‘opens up’ and becomes itself the ‘multi-layered’ courtyard. Even at this ultimate stage, the juxtaposition of the simultaneously present dualities interweaves the resulting spatial conditions, creating an abundance of experiential environments for its users.

Furthermore, the courtyard system has tried to grapple with the levels of privacy in many ways. The continuous transformation responds to the family’s ever-changing needs and therefore generates a big number of diverse spatial conditions: the entire house may be turned into an urban camping type of residence, or it can ensure the privacy of family members by creating a sequence of closed, independent spaces, or any possible combination of the two. The mixture of diverse activities simultaneously taking place, as well as the accommodation of completely disparate uses of the spaces, and their occasional transformation into a public space, in a way reflects the incessant fluidity of contemporary living in Cyprus.

Materiality - structural and natural elements as the main constituent members of a flexible, fluid courtyard: While traditional courtyards are surrounded by solid walls with openings, in this case study the materiality of the main constituent elements enhances the notion of the malleability of the courtyards. All the surfaces of the extensions are made of light materials, either glazed panes or wood panels that open or slide and, finally, almost disappear. While these architectural elements that define the courtyards disappear, the participation of the vegetation as part of this courtyard system is disclosed, gradually taking on the main role of the further, discreet levels of privacy. The vegetation is even used as material for balustrades or a swivelling shading device and becomes a vital architectural material in the system of the courtyard, while retaining its smell, texture, colours and life.

The fact that this specific case study questions and attempts to evolve the actual traditional courtyard system in its ‘motherland’, in other words in a listed house, generates new dynamic relationships which perhaps would not be achievable in a newly-designed contemporary building. The approach entails the merits of both the old and the current heritage, making indispensable the one to the other.

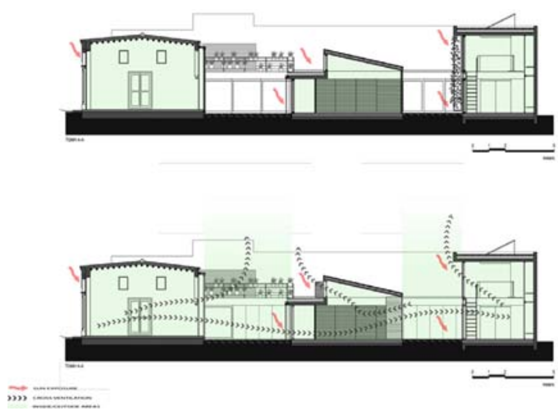

Figure 2: bioclimatic approach

Bioclimatic Approach as the Strategy of Physical Means to Generate Intangible Spatial Qualities: Originally, the decision to create a system of courtyards was in response to the climatic conditions (Serghides, D., 2010): to provide a south orientation for all the spaces with movable shading devices and cross ventilation. (fig.2) The amplification of the draft through the 'enforced' routes that are created in the semi and completely open stages of the house is filtered and cooled through the various shaded spaces and vegetation. The density of the light and draft is controllable by the movable elements of the courtyard, enabling the users to create the desired ambience and atmosphere of their physical oasis.

Although the qualities of contemporary life may have been to a large extent successfully transferred in this house typology, the feeling of an oasis that protects the users from the so-deemed 'negative' parameters of a modern town, like those of noise and the uncontrolled affluence of images, prevails. The user can orchestrate the desired environment by rearranging the conditions him/herself.

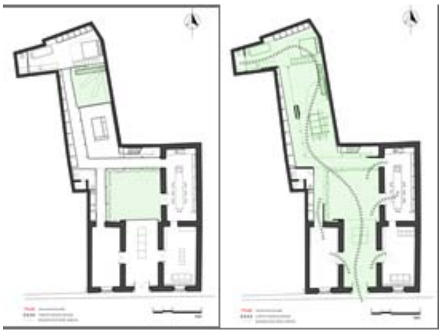

Figure 3: fluidity of spaces, activities, movements and air flow

Unexpected and Playful: The combination or overlapping of activities creates various unexpected relationships that can be enhanced by the rearrangement of the mobile constituent elements of the courtyards. The static and otherwise traditional centralised courtyard system may indeed fall into an inanimate state if it lacks the right proportions or ingredients. In this case, however, it succeeds in being transformed into a playful environment with unanticipated surprises that keep creativity alive and the mind free. These flux quality spaces (fig. 3) endlessly open up the desire for exploration and curiosity that, like a living entity, keep company to any user of the house.

Extending the courtyard system idea into the interior design: An implementation of this idea was taken a step further to the organisation of the interior spaces. A series of furniture was specifically designed for this house, which became spaces within spaces. Simulating the characteristics of the courtyards, they multiply their possibilities on different scales, incorporating further the corporeal and sensory qualities of the human being. This approach culminates in the design of the two multifunctional systems of furniture in the centre of the children's rooms. Like the courtyards themselves, they can function independently like enclosed boxes that open up to reveal various functions, such as sleeping, studying and playing, interacting first with the room and finally adding another layer to the courtyard system.

3 IMPLEMENTATION AND EVOLUTION OF THE COURTYARD SYSTEM IN A NEW URBAN CONTEXT A CENTRAL COURTYARD AND A NETWORK OF SATELLITE PERIPHERAL COURTYARDS IN A NEW NEIGHBOURHOOD OF NICOSIA (FIG.2)

A Central Courtyard and a Network of Satellite Peripheral Courtyards in a New Neighbourhood of Nicosia (fig.4)

A family project in a new neighbourhood of Nicosia, consisting of a main residential entity on the ground floor, two housing units for the two children of the family on the upper floor, and a working space for the teaching of Greek language and History, is organised around a central courtyard and a network of peripheral courtyards.

This newly developed part of Nicosia, like every other new development in the town, lacks any sort of identifying features. Planning regulations and the trend of building rather large homes conspire to pack houses within just three meters from the borders of the plots. The result is a sort of 'corridor' around each house, deplete of any vital outdoor spaces for family activities and suffering of any level of privacy.The character and nature of the specific users of the house and their understanding for the need of a living environment with humane qualities greatly contributed to the realisation of the proposed design, the core of which is the central courtyard. Their need for private outdoor spaces that neither faced, nor could be viewed from, neighbouring houses generated the idea of combining a central courtyard with satellite peripheral courtyards.

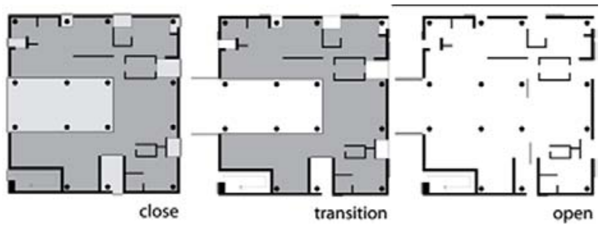

Figure 4: the 3 main phases of the courtyard system

Central courtyard: The public activities of the main residence gravitate around the central courtyard, which is defined by a transparent glazed material that enables the spaces to communicate with each other as well as with the outdoor space. For most of the year, the envelope of the courtyard vanishes through the 'shell' and out of the 'sculpted box' of the building, unifying the interior and exterior spaces. The outdoor activities mingle with the indoor ones while new dynamic relationships between them are forged.

Peripheral courtyard: The concrete shell of the 'box building' is sculpted with notches that function as a system of a peripheral network of courtyards with sliding perforated wood panels (fig.5). The panels, when closed, assure a level of privacy for all the internal spaces, since there is not a single opening on the actual skin of the building. When the panels are open, a dialogue with the surroundings opens up, reflected vividly in the transformation of the elevations. The system of courtyards acts as the facilitator between the built environment and nature and it is actually the only contact with the surrounding environment.

Figure 5: reflection of the peripheral courtyards on the elevations

Collaboration between the central courtyard and the network of peripheral courtyards: The system of small peripheral courtyards works together with the central one to subtly animate the interior spaces with controlled and diffused light, helping to achieve an almost 'sacred', soothing ambience in the house. It also manages to refresh and cool the spaces with continuous cross ventilation. Through the transformable envelope of the 'sculpted box' with its sliding panels, the user may alter the conditions of all the adjacent spaces, in turn transforming all other internal relationships.

Materiality- Hard and smooth/ Rigid and fluid: The harshness and almost unwelcoming attitude of the elevations, executed in fare face concrete, initially alienate visitors. It creates a hard shell that confines and protects the family activities. By its porosity, controlled by the users through sliding panels it allows the link with the external environment upon the users' will. As someone enters the house, however, he is taken by surprise: The softness and conviviality of the internal conditions generated by the central courtyard working in harmony with the network of peripheral courtyards make for a warm, nest-like atmosphere, flexible and easy to handle it for its inhabitants.

4 COURTYARDS DEFINED AND SCULPTED BY LANDSCAPE AND NATURE

Two houses on the outskirts of the small rural town of Dali were the starting point for an investigation into how the surrounding landscape redefines the main architectural element of the courtyard.

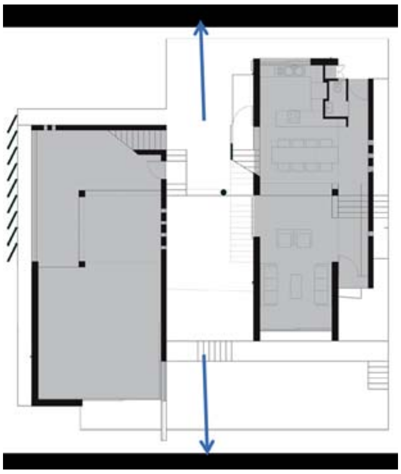

Figure 6: the landscape penetrates and defines the courtyard

Nature sculpts the sculptor's courtyard. The penetrating landscape (fig. 6)

The first case study combines a house with a sculptor's studio. The courtyard created here is flanked by the two elongated parts of the house and studio. The two narrow sides face the adjacent ascending hill, which descends through and sculpts the courtyard, inevitably focusing the attention on the faraway landscape and the prevailing mountain range of Pentadaktylos. The resulting levels of the courtyard correspond to the various domestic and artistic activities, which are enhanced by a network of movements that consequently transform the conditions of the courtyard.

The transformation of the 'atmospheres' of the courtyard culminates in the changes of the macro and micro natural environments, the vegetation, and the weather conditions, with the seasons taking on a main role in defining this specific courtyard. The spatial compositional elements of the courtyard respond to the climatic conditions, succeeding in directing and enhancing the air flow for cooling reasons, while protecting and shading from the summer sun, with the hovering volume of the bedrooms covering the central part of the courtyard.
The resulting transformations of the courtyard penetrate and enrich the internal conditions of the house and the studio through direct openings and loop systems of movements that are interwoven through it.

Multishaped courtyard merged in the nature (fig. 7)

This house was designed for a family with four children that wanted to live in close proximity to nature in a plot. The bedrooms and private spaces are organised as clusters of independent volumes that surround and envelop the family's communal activities.
A network of peripheral courtyards is formed between the solid private spaces, while its core is a structure gradually dissolves as its glazed transparent envelope opens up to its surroundings. It finally links and unifies the peripheral courtyard network, transforming it into a unified multi-shaped courtyard. It further extends into the surrounding natural environment, which in turn penetrates the courtyard.
In this case too, the changes in the natural surroundings - the orchard, the garden, the river bed, the eucalyptus cluster and the far away landscape - actively participate in and penetrate into the internal conditions and atmospheres of the courtyard and the living spaces of the house.

Figure 7: multishaped courtyards

5 IMPLEMENTATION OF THE COURTYARD TYPOLOGIES IN URBAN SCALE ENVIRONMENTS

The experimentation and research done for these realised case studies is rich material for pursuing this almost endless voyage of quest into the local architectural identity, focusing on the significance of the courtyard as the main spatial compositional element. The exploration continues on different scales and nature of use. The understanding of the courtyard spatial organisation can be seen as an urban feature pattern in horizontal and vertical development, continuously transformed in order to adjust to the natural, cultural, and social environment.

Decimal numbering of all sections is recommended (with the exception of the sections "ACKNOWLEDGEMENTS" and "REFERENCES"). If bold printing is not available to you, use underlining, instead, but only for subheadings and subsubheadings, not for Major Headings.

Courtyard qualities in a vertical development:

An apartment complex in a new urban area of the seaside town of Pafos is developed vertically. The expected, conventional type of compact, one-floor apartments is translated into three-story houses with outdoor spaces as large as the indoor ones, while the lack of greenery due to the restricted size of the plot prompts the creation of a vertical park. This strategy could be achieved through the introduction of a new network of courtyards on all the floors of the building. Each courtyard is unique, defined by the relationship to the houses themselves, the vertical park and the faraway landscape. It is constantly transformed through the changes in vegetation and natural phenomena.

Figure 8: network of courtyards of different scales

School environment with a dense network of courtyards of various scales (fig. 8)

Inspired by the surrounding urban environment, which in itself may be viewed as a network of courtyards formed by the plot and house planning, a network of a wide variety of courtyards becomes the strong spatial composition and organisation of the school. The project was a competition entry that attempted to tackle innovatively the issue of a local identity for a school environment. The dense network of courtyards offers various courtyards in a wide range of scale, which are actively transformed by the presence of students and their various activities, in small or big groups.

6 CONCLUSIONS

In each case, new parameters filter the decisions that lead to a new architectural language for investigating and developing the architectural element of the courtyards, picking up the thread of history's wisdom.
Following this methodology, the final design cannot be predicted. It rather results from the meticulous analysis and clear understanding of the existing conditions [(Tarkofsky, 1986):in relationship to the response to the current and future needs of the people, town and the society. The inherent wise merits of the spatial organisations of the courtyard system ensure the respond to the cultural, social and environmental qualities of each project. In other words it carries and offers the richness and wisdom of the tradition. At the same time, the integration of gained knowledge and influence form the advanced technology and the methodologies of the spatial organisations developed in other countries may contribute the most for the improvement of the living conditions. The confluence of both parameters could be the generator of achieving innovative solutions for each specific situation. This approach becomes the way out to maintain, develop or (re)create an identity that derives from the tradition and targets to innovative solutions in order to respond to the constant changes and needs.

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DEVELOPMENT OF TOOLS AND TECHNIQUES TO SURVEY, ASSESS, STABILISE, MONITOR AND PRESERVE UNDERWATER ARCHAEOLOGICAL SITES: SASMAP.

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KEY WORDS: Underwater cultural heritage, in situ preservation, location, assessment, management, monitoring,

ABSTRACT:

Development of Tools and Techniques to **S**urvey, **A**ssess, **S**tabilise, **M**onitor and **P**reserve Underwater Archaeological Sites (SASMAP) is an EC funded project, with the purpose of developing new technologies and best practices in order to locate, assess and manage Europe's underwater cultural heritage in a more effective way than is possible today. SASMAP will take holistic- and process- based approaches to investigate underwater environments and the archaeological sites contained therein. SASMAP will benefit the management of underwater cultural heritage in Europe and in the rest of the world by providing valuable tools to plan the preservation of offshore archaeological sites and their contents in accordance with both the Treaty of Valletta (1992) and research driven investigations.
The need for SASMAP is based on the results from previous and current EU initiatives, the networks resulting from these projects and on-going research at the consortium's institutions. Within SASMAP a holistic approach will be taken to locating, assessing, monitoring and safeguarding underwater cultural heritage. This will involve developing and utilising tools and technologies to allow "down-scaling" from the large scale regional level, moving on to the local site level and finally to the individual components of a site. Results obtained from the down-scaling approach at the proposed study areas will show the effectiveness of such an approach for locating and detailed mapping of archaeological sites and their preservation potential. The end results of this approach will be used to develop a plan for assessing archaeological sites in European waters. From a management point of view this is an up-scaling approach to planning (bottom up). All information and experiences obtained during the course of the project will be utilised to enhance and develop existing legislation and best practice for mapping and preserving Europe's underwater and coastal heritage. The project started in September 2012 and the aim of the paper is to give a brief introduction to the project.

1. CONCEPTS AND OBEJCTIVES

1.1 What is SASMAP?

SASMAP's purpose is to develop new technologies and best practices in order to locate, assess and manage Europe's underwater cultural heritage in a more effective way than is possible today. SASMAP will take holistic- and process- based approaches to investigate underwater environments and the archaeological sites contained therein. This is necessary regardless of whether or not investigations are research driven or in connection with sub-sea development. Investigations of underwater heritage which are associated with subsea developments in Europe often require pre-disturbance studies to comply with the Treaty of Valletta (1992).

Cost effective methods to locate and assess the dimensions of archaeological sites both on and beneath the seabed are essential. The presence and extent of potential threats to archaeology must also be determined. Threats may arise from the natural physical environment including strong currents, from manmade hazards such as dredging, from construction work, fishing, installation of pipe/cable lines and development of recreation centres. The stability of the site and the state of preservation of the artefacts present must also be assessed. The various assessments provide information on how best to approach or manage a site. If the physical and bio-/geochemical environments are unstable or pose a threat to the site, the opportunities for stabilising it in situ must be determined. The options for monitoring the continued integrity of the site must be identified. If none exist, it needs to be determined whether areas can be identified that need to be excavated, or sampled non-destructively, before information is lost.

The results and products of the project fulfilled the scientific requirements of the call for proposals ENV. 2012.6.2-6. Development of advanced technologies and tools for mapping, diagnosing, excavating and securing underwater and coastal archaeological sites.
It is hoped that SASMAP will benefit the management of underwater cultural heritage in Europe and in the rest of the world by providing valuable tools to plan the preservation of offshore archaeological sites and their contents in accordance with both the Treaty of Valletta (1992) and research driven investigations.

1.2 Why SASMAP?

The need for SASMAP is based on the results from previous and current EC initiatives, the networks resulting from these projects and on-going research at the consortium's institutions. The proposed pan- European consortium includes partners who have been involved in previously funded and successfully completed projects related to underwater cultural heritage, namely The MoSS Project (http://www.mossproject.com/), MACHU (http://www.machuproject.eu/), BACPOLES (no existing website) and Wreck Protect (http://wreckprotect.eu). In addition, partners have also worked in The Baltic Gas Project (http://balticgas.au.dk/) and The Balance Project (http://www.balance-eu.org/) reflecting the interdisciplinary nature of the consortium. It also contains partners from the networking opportunities provided by the COST Actions IEO601 Wood Science for Conservation of Cultural Heritage (WoodCultHer) and TD0902 SPLASHCOST concerning submerged prehistoric landscapes. Many of these projects are directly related to the current ethos within maritime archaeology and conservation, namely to preserve underwater cultural heritage in situ, that is to say where it lies on or in the seabed. Within Europe this has been politically galvanised by the Valetta treaty (1992) and internationally by UNESCO's Convention for the Protection of the Underwater Cultural Heritage (2001). Both these treaties advocate that, as a first option, the underwater cultural heritage should be protected in situ and, where possible, non-intrusive methods to document and study these sites in situ should be used. This is understandable in terms of the underwater cultural heritage resource. UNESCO currently estimates that, "over 3 million wrecks are spread across ocean floors around the planet" (http://www.unesco.org/en/the-underwater-cultural-heritage/underwater-cultural-heritage/wrecks/). This figure does not include the numerous submerged landscapes (and archaeological sites therein), found around Europe as a result of postglacial sea level change.

The North Sea, adjacent to the Netherlands, is effectively one large submerged prehistoric landscape consisting of settlements dating back to the Pleistocene. It is financially prohibitive in either research- or development lead investigations to excavate, conserve and curate the many finds. In Danish territorial waters alone, it is estimated that there are 20,000 submerged settlement sites lying around the present day coastline and out to a water depth of 30 – 40 metres. The recently completed EU supported project WreckProtect (http://www.wreckprotect.eu) carried out a cost benefit analysis for the costs of excavation, conservation and curation versus in situ preservation. A single large wooden wreck, such as the Mary Rose in the UK, has to date cost ca. 80 million Euros to raise, conserve and exhibit, whereas the physical in situ preservation of a similar sized wreck in Sweden cost around 0.07 million Euros.

Even though at first glance it appears to be several orders of magnitude more economical to preserve an archaeological site in situ, efficient and well informed management requires significant investment of resources to continually monitor and safeguard these sites. SASMAP will develop and assess tools, techniques and methods in order to develop best practice for the cost effective and successful investigation and management of underwater cultural heritage

1.3 The SASMAP Concept

Within SASMAP a holistic approach will be taken to locating, assessing, monitoring and safeguarding underwater cultural heritage. This will involve developing and utilising tools and technologies to allow "down-scaling" from the large scale regional level, moving on to the local site level and finally to the individual components of a site as shown in Figure 1.

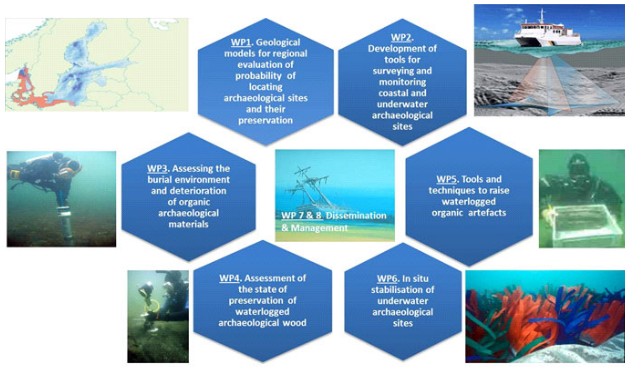

Figure 1. A down-scaling and up-scaling approach to locating, assessing and managing underwater cultural heritage.

Results obtained from the down-scaling approach at the proposed study areas will show the effectiveness of such an approach for locating and detailed mapping of archaeological sites and their preservation potential. The end results of this approach will be used to develop a plan for assessing archaeological sites in European waters. From a management point of view this is an up-scaling approach to planning (bottom up). All information and experiences obtained during the course of the project will be utilised to enhance and develop existing legislation and best practice for mapping and preserving Europe's underwater and coastal heritage.

1.4 The SASMAP Consortium

SASMAP brings together a consortium of seven research institutions and four Small Medium Enterprises (SMEs) from seven European countries. The partners comprise an interdisciplinary group with the SMEs having expertise in the development and production of state of the art marine geophysical instruments, equipment for measuring bio-geochemical parameters in the marine environment, protection of sub-sea installations (pipelines, cables) and hand held diving tools. Institutional partners encompass synergistic group researchers in marine archaeology and conservation, in situ preservation, wood degradation, marine geochemistry and marine geophysics working in museums, universities and governmental institutions with relevant know-how, facilities and resources to realise SASMAP.

Participant no.	Participant organisation name	Country
1 (Coordinator)	The National Museum of Denmark (**NM**)	Denmark
2	Innomar (**IMAR**)	Germany
3	Unisense (**UNI**)	Denmark
4	AKUT (**AKUT**)	Denmark
5	Seabed Scour Control Systems (**SSCS**)	United Kingdom
6	Geological Survey of Denmark and Greenland (**GEUS**)	Denmark
7	The Viking Ship Museum (**VM**)	Denmark
8	Cultural Heritage Agency of the Netherlands (**RCE**)	The Netherlands
9	University of Gothenburg (**UGOT**)	Sweden
10	Superior Institute for Conservation and Restoration (**ISCR**)	Italy
11	University of Patras (**UPAT**)	Greece

Table 2. The partners of the SASMAP consortium.

2. RESEARCH & INNOVATION WITHIN SASMAP

SASMAP has multiple scientific objectives that all have as their aim to develop a structured and optimized approach to safeguarding underwater cultural heritage. The objectives are divided up into the following Work Packages (WPs):

2.1 A Geological model for regional evaluation of probability of locating archaeological sites and their preservation potential (WP1).

Marine geological investigations are essential to develop a model describing the palaeogeographical and depositional environments in the selected study areas. GEUS has substantial experience in investigating the postglacial geological development of the Baltic Sea region. The study will be deployed in the initial phase of the project to reconstruct the palaeo-landscape and to build a geological model of the Baltic target site. Existing information from this multi-disciplinary field will include seismic, sedimentological, biostratigraphic and AMS C-14 dating data, which will be collated. Based on these data the changing geological environments, as well as the palaeogeography, will be reconstructed with respect to sedimentary conditions and water level fluctuations that occurred in the course of the various postglacial lake stages, as well as regional sea level changes.

On the basis of the geological model it will be possible to optimise the process of selecting the target region ideal for non-destructive down-scaling studies, spanning from regional satellite scanning of theoretical optimal target coastal areas, detailed multibeam echosounder and shallow seismic surveying of selected target areas to 3D-seismic investigations of identified archaeological target sites.

All data will be applicable to GIS presentation, interpretation and modelling of the physical appearance of the archaeological sites. The GIS will be custom made for input of hydrodynamic and sediment regime data for evaluation of site stability and preservation status.

Similarly, the University of Patras (UPAT) has for decades in cooperation with the Finnish Institute at Athens, University of Peloponnesus, Hellenic Institute of Marine Archaeology (IENAE) and Ephorate of Underwater Archaeology of Greece (Hellenic Ministry Of Culture and Tourism) carried out marine-geological investigations in Greek waters focusing on palaeo coastal morphology in archaeological sites of Greece (Cape Sounio, Poros and Dokos Islands, Killini, Neapoli). UPAT has experience in investigating ancient submerged archaeological sites and reconstructing the coastal palaeogeography in the eastern Mediterranean Sea. Aegean shorelines usually are characterized by rocky and narrow (and steep) coasts with low sediment accumulation rates. Today most of the prehistoric and historic coastal settlements (harbour and cities) in Aegean Sea, lie underwater due to postglacial transgression, local tectonics and intense coastal dynamics.

These models will be supplemented with input from partners 8 (RCE) The Cultural Heritage Agency of the Netherlands. RCE has a long standing tradition in researching the seabed with the help of other (governmental) institutes such as Rijkswaterstaat. Their previous works have resulted in large scale and small scale models published within the EU- Culture 2000 project MACHU. Within SASMAP the models will be combined to produce maps of individual archaeological value and potential, which will be incorporated into the existing MACHU GIS. The final product will provide the basis for improved decision making when planning subsea development or investigating and preserving known sites in situ.

2.2 Development of Tools for Surveying and Monitoring Coastal and Underwater Archaeological Sites (WP2)

Mapping and monitoring of an archaeological site is a prerequisite for determining its location, its extent and for assessment of its physical stability. Remote sensing techniques are one of the most cost effective tools for regional scanning of the seabed surface, sediments and their morphology as well as assessing the physical stability of archaeological sites. State of the art satellite imagery techniques are now able to monitor changes in coast line morphology and sediment transport in shallow water environments (to depths of 6-8 metres). SASMAP will be one of the first projects to use such remote sensing techniques to monitor coastal changes. On underwater sites, sidescan sonar, sub-bottom profilers, magnetometers, and single and multibeam echosounders have been used to locate and map archaeological sites both on and within the seabed. Although the use of these tools is not new to marine archaeology, development of existing technologies is one of the significant impacts of the SASMAP project. By contrast, 3D shallow seismic is surveying a cutting edge method and together with other new technologies developed within the project, will give detailed 3D imagery of archaeological sites and environs.

Following a down-scaling approach, i.e. working from the large regional scale to the detailed site scale, will yield seamless maps that can be used for assessing coastal and submerged archaeological sites. This will be achieved by the following:

- satellite imagery for case study areas (Denmark and Greece) will be purchased from a satellite image providing company and assimilated into a Geographical Information System (GIS), in order to map the coastline and sediment transport in 3D. The development and use of the GIS will contribute to developing a best practice for large scale assessment of the coastal and foreshore zone.
- the stability of the case study areas will be investigated through observing the 3D terrain models of the sea bed surface area obtained from multibeam echosounder (MBES) surveys over the case study areas during the project time span. These data will also be assimilated into the GIS and by comparing data sets from the satellite imagery with MBES data, hot spot areas of the sites which are being eroded, due to sediment transport or conversely covered with sediment, will be identified. These areas will be verified (ground truthed) in connection with research undertaken in WPs 3, 4 and 6.
- A prototype 3D parametric sub bottom profiling system (SBP) will be applied to the area at a local scale in order to obtain a 3D map of the sediment structures and to identify archaeological artefacts within the site. This system has not previously been used in shallow water and will be trialled alongside a proprietary ‘CHIRP’ SBP system, currently considered the best commercially available tool for imaging buried archaeological artefacts. The potential application of this new system to archaeological prospection will thus be assessed. These data will also be assimilated into the GIS. Trialling the prototype system on the site in Greece where the carbonate bedrock is very different to the postglacial and glacial sediments typical of north-west Europe, will evaluate its range of applicability to marine archaeology. A GIS will be developed using state of the art remote sensing techniques and data in order to holistically localise, map and monitor archaeological remains in submerged environments on a large scale.

2.3. Assessing the burial environment and deterioration of organic materials (WP3)

Buried waterlogged environments provide unique conditions for organic materials such as wood, bone, antler, textile, skin and plant remains to be preserved for millennia, partly due to the low oxygen levels. Conditions in open seawater can, in the absence of wood boring organisms (see http://wreckprotect.eu) also preserve these materials for many hundreds of years. However, deterioration of organic material can occur in oxygen free (anoxic) environments due to the activity of anaerobic bacteria. Research into the reburial of archaeological materials in the marine environment has shown that the rates of organic turnover (deterioration) are dependent on sediment type and their pore water composition (http://www9.vgregion.se/vastarvet/svk/reburial/index.htm).

The project will develop tools and methods to:

- improve sampling techniques for sediments, not only for the purposes of this project, but archaeology in general (dating, pollen and other environmental analyses). Currently available diver operated coring devices can be notoriously difficult to use in terms of deployment, retrieval and obtaining deep and undisturbed sediment cores. A diver deployable vibrocore-type coring system, will be constructed and tested by AKUT and NM, which can sample sediments down to a maximum sediment depth of 50 cm and without disturbing the surface layers of sediment which are very difficult to sample due to their often mobile nature. The corer will be constructed in such a way that discrete layers within sediments (taken both vertically and horizontally) can be easily sub sampled in order to characterize both sediment type and porewater composition in the laboratory. The device will be used for ground truthing other elements of this and other work packages
- develop a data logging system which can be deployed for periods of up to six months to assess pore water composition of sediments in situ to a maximum sediment depth of 50 cm. Proposed parameters to be measured are dissolved oxygen, sulphide content, pH, redox potential and methane, which in combination provide information on the biogeochemical process on going in the sediment and their effect on organic material turnover. This data logger will be developed by partner 3 (UNI), who are world leaders in development of microsensor technology for use in underwater and marine environments

The developed tools will be used to obtain sediment samples and monitor conditions on the test sites in order to better understand why artefacts are so well preserved, archaeologically speaking, and determine which sediment types offer the optimal conditions for preservation should sites be preserved either in situ or through re-burial. The results of this environmental monitoring will also be compared and contrasted with microscopic analysis of representative samples of archaeological wood, carried out by partner 9 (UGOT) from the sites in order to contribute to our understanding of the effects of the environment and deterioration process of waterlogged archaeological wood. Similarly the results will be compared and contrasted with the data obtained by the 3D sub bottom profiler. The EU financed project Baltic Gas (http://balticgas.au.dk/balticgasaudk/) has shown the possibility of monitoring methane development with similar equipment. In this manner it may be possible to use this tool not only to localise artefacts but also characterise the biogeochemical processes on-going in the sediment to assess the preservation capabilities of sediments.

2.4. Assessment of the state of preservation of waterlogged archaeological wood (WP4)

Waterlogged wood is one of the most frequently encountered materials on underwater archaeological sites, and knowledge of its state of preservation whilst still in situ determines whether it can be raised and subsequently conserved, or whether it is sufficiently strong to withstand being preserved in situ. As noted previously, anaerobic bacteria cause deterioration of archaeological materials in marine sediments and, in the case of wood, they utilise the sugars and complex carbohydrates present in the wood cell wall as a source of nutrition. As deterioration proceeds material is removed and subsequently replaced with water – it is this water which fills the “voids” and allows the material to retain its form. Thus although freshly excavated wood may appear well preserved from an archaeological perspective, i.e. surface details and form are retained, it can be poorly preserved from a conservation perspective and if allowed to dry in an uncontrolled manner it will suffer irreversible shrinkage and collapse.

Within SASMAP a prototype hand held tool for assessing the state of preservation of waterlogged archaeological wood both in situ on the seabed and in the laboratory will be developed. This prototype will be based on research and development work which has been on going by partners 1 (NM) and 4 (AKUT). The prototype will be based on the non-destructive determination of the density of the wood. The net effect of bacterial deterioration is that as cell wall material is removed and replaced with water the density of the wood decreases - the more degraded the wood the lower the density. Density is a good physical parameter to provide information about the condition of wood and the implications this has for subsequent conservation or suitability for preservation in situ. Currently there is no device commercially available that can provide this information for marine archaeologists and conservators. Furthermore such a device could have broader implications for the non-destructive testing of non- archaeological timbers used in the marine environment (pilings, harbour installations) or on land (forestry, construction industry).

2.5. Tools and techniques to raise waterlogged organic archaeological artefacts (WP5).

Due to their fragility, organic archaeological materials from underwater sites can be challenging to excavate, support, raise and transport to conservation facilities. This is due to the inherent difficulties of working underwater (limited time and potentially harsh conditions) and in particular the crucial stage of lifting artefacts from the seabed to the surface where mechanical damage can easily occur. Submerged prehistoric sites in particular contain a wealth of the aforementioned organic materials and complex structures such as fish traps. To surmount this, artefacts are often raised on supporting materials or in sediment blocks (block lifting), whereby the artefact is excavated with surrounding sediment and subsequently excavated under controlled conditions on land in the laboratory. Methods of encapsulating and block lifting have been used in the past to address this, yet can be very time consuming underwater, with artefacts being left exposed to physical damage at crucial stages while consolidating materials are allowed to “set” underwater.

SASMAP will draw upon the extensive excavation experience of partner 7 (VM) and the pioneering research into stabilising and consolidating archaeological remains underwater of partner 10 (ISCR) in order to develop best practice methods. This will involve the development of the use of polymer based consolidants which can both encapsulate and consolidate sediments, as well as freezing of sediments in order to enable the safe lifting and transport of waterlogged organic archaeological objects.

2.6. In situ stabilization of underwater archaeological sites (WP6)

Sites which are preserved in situ are threatened by the effects of underwater currents which can cause sediment to be removed from sites, leading to their exposure. Upon exposure, sites are susceptible to mechanical abrasion and erosion, which can lead to their total loss. Furthermore, wooden artefacts can, under the right environmental circumstances, be attacked by wood boring organisms such as shipworm, which can also lead total loss of archaeological materials within relatively short periods of time – years or decades rather than centuries or millennia. The EU supported project Wreck Protect (http://www.wreckprotect.eu) assessed ways to protect historical wooden shipwrecks in situ from the threat of wood boring organisms. All potential methods identified relied upon limiting the access of oxygen to the wood and this can most simply be achieved by covering with sediment. However, simply covering with sediment may not be sufficient as it may itself be washed away. Innovative methods identified actually took advantage of currents and sediment transport within the water column to either entrap sediment and create a burial mound or disperse currents so that seabed erosion was reduced. Partner 5, (SSCS) is a world leader in scour control systems to prevent seabed scouring and erosion for the offshore industry (gas and oil pipelines, offshore windturbine footings). To achieve this they use mats of artificial seagrass, which float upright in the water column and entrap passing sediment particles, effectively creating an artificial seabed. These mats will be developed further to test their applicability to protecting shallow water submerged archaeological sites, which are under threat from near shore and coastal erosion. Furthermore, the durability of materials that have typically been used to stabilise submerged archaeological sites in the marine environment, including sandbags, plastic sheeting, geotextiles and debris netting, will be tested.

3. IMPACTS OF SASMAP

SASMAP with its holistic and process based approach to underwater cultural heritage will provide an improved understanding of the environment of underwater archaeological sites, and contribute to best practice for management decisions. Although in situ preservation should be seen as a first option for the preservation of underwater cultural heritage this is not always viable due to either the nature of the site environment or the fact that, due to subsea development, sites have to be excavated. SASMAP addresses both these scenarios. The innovative tools and new technologies that will be developed to improve both location and mapping of sites; the excavation and raising of fragile organic materials if it is not viable to preserve them in situ. If in situ preservation is an option, SASMAP will also see the development of new technologies to stabilise sites and monitor their effectiveness and also the effects these stabilisation materials have on the environment.

The SASMAP consortium includes four SME partners. The SMEs are already leaders in their respective fields and the project is mutually beneficial as it provides the SMEs the opportunity to fulfil many of their own business development plans and develop new tools and technologies. The impact of these new technologies has wider implications than just the SASMAP project and will enable the SMEs to increase their business profiles after the completion of the project.

SASMAP is adopting a European rather than a national approach because the implications of the Treaty of Valletta affect all European nations with territorial waters and thus responsibility for dealing with underwater archaeology

The development of the SASMAP technologies requires strong collaboration between complementary research disciplines that are only found at a European level. Moreover, the involvement of four SMEs in the project is only possible due to the European approach taken. The active involvement of these SMEs will ensure awareness and effective dissemination of the technologies to heritage agencies, cultural resource managers and end users in the offshore sub sea industry. These activities are of vital importance for successful exploitation and marketing of the technologies beyond SASMAP. By taking a European approach, SASMAP will improve the assessment of underwater archaeology in connection with sub sea development by providing heritage agencies with new tools and best practices

The project will produce two main products; Prototype technologies, and other tools and methods which will contribute to best practice when investigating underwater archaeological sites. The prototype tools developed by the SMEs will be disseminated through both the project's own home page and the home pages of the SMEs involved along with media (TV, radio, press) coverage. Intellectual property of the prototypes will be the rights of the SMEs but directions for their practical use will form an integral part of the guidelines produced in the project. The new technologies developed by the SMEs will be promoted through the field school that will take place at the end of the three year project. Furthermore, the tools and techniques developed to locate, assess and manage underwater cultural heritage will be synthesised into two guidelines. These will be made available to stake holders, end users and policy makers at the field school and on the project home page as downloadable pdf files in order to make them freely available.

Further to the prototypes and the guidelines, the project results will be disseminated through publication in peer reviewed scientific journals, popular press, presentations at national and international conferences for marine archaeology, conservation and subsea development. It is also hoped that the project can contribute to European policy for the improved management of Europe's underwater cultural heritage.

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AN INTERDISCIPLINARY APPROACH TO THE PRESERVATION OF THE GAIOLA ARCHAEOLOGICAL UNDERWATER PARK AND THE POSILLIPO COASTLINE, BAY OF NAPLES (SOUTHERN ITALY)

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ABSTRACT:

The aim of this paper is to present ten years of underwater archaeology investigations in the Marine Protected Area "Gaiola Underwater Park" in Naples, Southern Italy since its institution in 2002. These results are at the basis of a development plan that is now the starting point for new research aimed to create a model of enhancement for the underwater archaeological heritage in the Mediterranean context. The project is developed by an interdisciplinary group of young researchers so that all the issues correlated with the marine environment can be taken into account.

1. INTRODUCTION

The Marine Protected Area "Gaiola Underwater Park" formally came into being with the interdepartmental ministerial order signed by the Italian Government in 7/8/2002. The Underwater Park takes its name from the two small islands a few meters off the Posillipo coastline in the Western part of the Bay of Naples, in Southern Italy. The local governmental authority in charge of the management of the area is the "Soprintendenza Speciale per i Beni Archeologici di Napoli e Pompei". With its 41,6 hectares this Marine Protected Area (MPA) is the smallest in Italy and is unique not only for its archaeological and historical heritage but also its environmental riches (Simeone & Russo, 2005). It is divided into "Integral Reserve Area" (A Zone), which is under a strict preservation order, and a "General Reserve Area" (B Zone) where there are fewer restriction (Figure 1). Together with the Pausilypon archaeological Park[1] this MPA is a naturalistic and archaeological treasure and that is why it is so important to protect it.

The Posillipo coastline is in fact the only stretch of coastline for more or less 50 km (from the town of Castellammare to the town of Pozzuoli), which has preserved its original environment, while all around the landscape has been completely destroyed by decades of violent urbanization and industrialization. To preserve the area and its cultural heritage has been and is extremely problematic, the main reason being the Park's difficult social and territorial background which affects it negatively due to the continuous and extreme anthropic pressure via both land and sea. Unfortunately, this problem is exacerbated by the lack of a adeguate policy of management of the coastline. The aim of this paper is to explain how in the last ten years, a collaboration between the Soprintendenza Speciale per i Beni Archeologici di Napoli e Pompei and the Centro Studi Interdisciplinari Gaiola onlus (CSI Gaiola), a local NGO active on the territory, initiated an important development and preservation process of this incredible area, demonstrating the significant role of scientific research and the use of technological instruments such as GIS and underwater surveys to obtain these results.

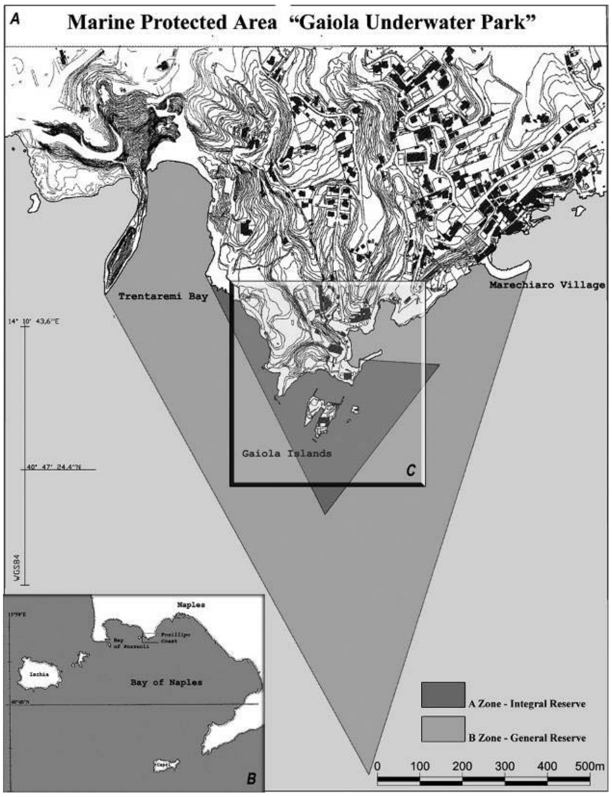

Figure 1 A) Studied area: MPA "Gaiola Underwater Park" ; B) Location of Posillipo Coastline in the Bay of Naples; C) Location of Studied Sub-Area.

1.1 The Archaeological Context

The hill of Posillipo encloses the Bay of Naples to the north-west, separating it from the Bay of Pozzuoli and acting as a breakwater between the western and the eastern sectors of the city of Naples. Geologically it is part of the volcanic system of the Phlegrean Fields representing the eastern edge of the caldera

[1] This paper will mainly focus on the problems connected with the management of the MPA "Gaiola Underwater Park"; but because the two are strictly connected it is important to at least mention the Pausilypon Archaeological Park.

that formed following the Neapolitan Yellow Tuff eruption (15 ka: Deino *et al.*, 2004). From the geo-morphological viewpoint the coastal sector, which is almost entirely rocky, presents a marked contrast between the western stretch of the Gaiola Islets (from which the MPA takes its name) characterized by the high cliffs (up to 150 m. above the sea level, where the Pausilypon Archaeological Park is situated), and the eastern stretch where the hillside gently slopes towards the sea. Since the 1st century B.C. this latter coastal tract has been densely inhabited, as witnessed by the numerous Roman remains to be seen along the coastline both above and below the surface of the sea. The name of the hill itself derives from the Roman villa of *Pausilypon* (an ancient Greek word which meant "place where all sorrow ends"), the remains of which have been identified in the area extending from the Trentaremi promontory to the area of Marechiaro. The villa was built by the Roman Equestrian knight Publius Vedio Pollio in the 1st century B.C., on whose death (15 B.C.) under the reign of the Emperor Augustus, it became part of the imperial estate (Vecchio, 1999). This villa, which underwent modifications and extensions throughout the centuries, is one of the most typical examples of the seaside properties of the Roman elite at the end of the Republican Age; at that time for the Equestrian class it became common to build luxurious villas by the sea and enriching them with private harbours and fishponds (Rustico, 1999). The remains of the Pausilypon villa are now technically divided between two archaeological areas: The Pausilypon Archaeological Park (on land) and the Gaiola Underwater Park (submerged in the sea). Both Parks are under the authority of the Soprintendenza Speciale per i Beni Archeologici di Napoli e Pompei, but are run by two different departments; in both areas the Soprintendenza is helped by the CSI Gaiola in the preservation, organization and enhancement of the sites and in the research activities. Nowadays the remains of this important seaside *villa* lie partially underwater because of ground movement and the consequent subsiding of the original coastline due to volcanic-tectonic activity (Günther, 1903; Simeone & Masucci, 2009).

In fact, geologically, the Posillipo hillside is a part of the Phlegrean Fields Volcanic System, because it forms the Eastern border of a caldera which originated after the so-called Neapolitan Yellow Tuff Eruption (Deino *et al.*, 2004). All this area of the Phlegrean Fields is affected by the volcanic-tectonic phenomenon called bradisism (from ancient Greek = slow movements) ground movement which causes the ground to subside or rise. For this reason in the Gaiola area many parts of the *Pausilypon* villa, in particular those structures that in Roman times were built very close to the sea, lie underwater. In the A zone of the MPA approximately 56% of the seabed is noticeably characterized by a hard tuff substratum and it is clear that almost all the hard substratum was radically disturbed by excavation work carried out in the Roman times for the construction of landing stages, communication trenches and coastal buildings, but especially for fishponds and the channel-system necessary for changing the fishpond water. The most interesting archaeological features of the area are: the private harbour built with the *opus pilarum* technique, an artificial canal, a nymphaeum, coastal cavities and the fishpond for the breeding of moray eels (Simeone & Masucci, 2009; Simeone et al., 2008; Simeone et al., 2010).

Thanks to the presence of this incredibly rich underwater archaeological heritage it has been possible to estimate the relative sea-level variation in this area (Simeone & Masucci, 2009). Unfortunately this huge heritage was completely abandoned for decades (Caputo, 2004), and before the institution of the Park in 2002 it was not preserved in any way.

The others remains of the *Pausilypon* villa found in the Pausilypon Archaeological Park there is what is left of a theatre that had a seating capacity of 2000 people, a small *Odeion* and the impressive Seiano Tunnel (a passage of 770 m. long and with a maximum height of 14 m. dug out in the Posillipo hillside).

It also has to be said, that even after the Park was formally established ten years ago, serious problems had to be solved in order to protect and develop these remains, because of their difficult social and territorial context. In fact, the Park is in one of the few areas in Naples where people have access to the sea and so can go swimming or boating for free (there are lidos in Naples but they are expensive), and for this reason the park is exposed to great anthropic pressure.

At this point it might be interesting to consider some of the results which ten years of activity in the Park have brought about, also thanks to a new but growing interest in this archaeological area and the new discoveries that have been made possible by instruments and methods like the GIS and the underwater archaeological survey.

2. NEW SURVEYS AND TECHNOLOGY

The Posillipo hillside Roman *villa* was included in the Phlegrean Fields residential system, where all the Roman aristocracy had property and sea-side *villas* for *otium* (D'Arms, 2003); but unlike the rest of the Phlegeran Coast (Pozzuoli, Baia, Bacoli, Miseno), where specific studies have been carried out not only from purely archaeological but also from the geo-archaeological viewpoints, research into the Posillipo coastline still mostly refers back to R.T. Günther's excellent work dated 1903. In Günther's work not only the surveying and the mapping of the submerged archaeological structures along the coast were carried out for the very first time, but, on the basis of his findings, an estimation of the relative sea-level variation (RSLV) was also made (Günther, 1903, 1913); an evaluation subsequently reviewed first by L. Jacono in 1913 and then by M. Pagano in 1981, whose work is mainly based on the interpretation of aerial photographs. In 2006 the Centro Studi Interdisciplinari Gaiola Onlus began to implement the knowledge on the Gaiola underwater heritage and the RSLV in the area through new surveys, also because, naturally, the previous research in the area was limited by the fact that when it was realized it was impossible to scuba dive. Thanks to these studies a new geo-referenced map of the underwater archaeological structures and of the many coastal cavities has been created and, new hypotheses on the RSLV on the Posillipo coastline since Roman times have been formulated (Figure 2). In this way it has also been possible to give some explanation to the present coastal geo-morphology of the area, enhancing not only the archaeological of the area, but also the environmental-geological value of the area. The first study phase was aimed towards the elaboration (through CAD software) of a detailed geo-referenced map of the submerged structures. Data acquisition was carried out in free diving (without underwater breathing apparatus) through *visual census* transects, with wide-range observation, planned on the basis of aerial photograph analysis, followed by detailed surveys of the structures listed below, and carried out by using underwater breathing apparatus. The surveys were made on the submerged archaeological structures and generally all the conspicuous geo-morphological elements ascribable to the anthropic reorganization of the tuff substratum or to sea erosion (wave cut notches, abrasion platforms, etc.).

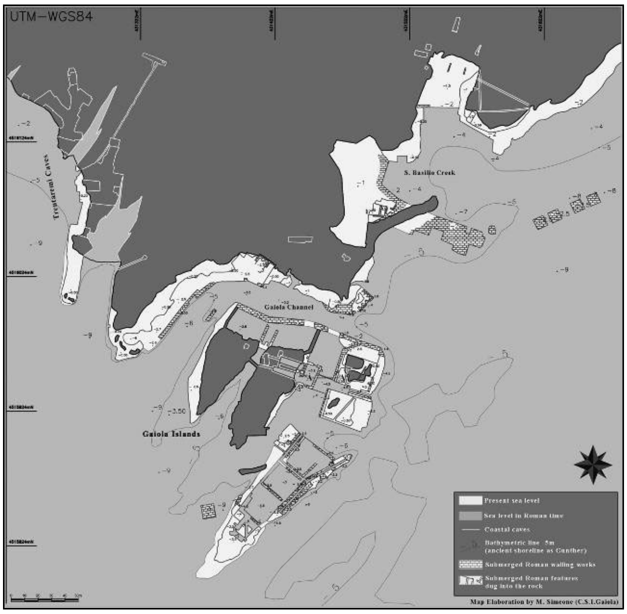

Figure 2 - Archaeological relief of the submerged structures and coastal caves in the studied Sub-Area, with indication of current sea level and estimated Roman sea level. (Map Elaboration by M. Simeone-C.S.I.Gaiola©)

At the same time, a census was made by carrying out the detailed planimetric survey of the cavities considered most significant from the historical and geo-morphological point of view.

In the second part of the study the archaeological and geo-morphological data were combined, and then some hypotheses on the use of the underwater structures and on the reconstruction of the coastline as it looked in Roman times were made. As regards the use of archaeological data in the calculation of the RSLV in the last 2000 years, it was possible to refer to some markers such as cavities, landfalls and then above all the fishponds. The importance of the Roman fishponds in studies of this kind in the Mediterranean Area has been recognized by various authors (Schmiedt, 1972; Pirazzoli, 1976; Lambeck *et al.*, 2004; Anzidei *et al.* 2005; Marriner & Morhange, 2007).

The reliefs were realized by using a pole with a metric graduation for all the structures lying at a maximum depth of 2 m., and by using depth gauges for structures lying at a greater depth. To map the structures lying more than 10 m. from the coastline a portable GPS was used. At the same time, during the data acquisition using GPS, reliefs on land were made with a survey compass and using the position of some known points on land as reference. All the acquired data was standardized by analysing tide gauge and meteorological data, in order to make uniform the sea level heights. All the data acquiring campaigns were recorded on camera and documented by videoing.

This campaign demonstrated the great historical/archaeological and environmental/geological relevance of the Gaiola Marine Protected Area. The new reliefs made a new, detailed view of the area's archaeological system possible, and, at the same time, the structures, especially the moray eel fishponds, were fundamental to calculating the RSLV (Figures 2-3). In fact, thanks to a 1st century B.C. Latin treatise on how to construct a fishpond according to the seabed and the fish you needed to breed (Columella, *De Re Rustica, Liber VIII*), it is possible to estimate which part of the fish pond was supposed to be underwater and which not in Roman times. The data acquired in the moray eel fishponds show that the sea level in Roman times was at least 3 m. lower than it is now (the estimation takes into consideration not only the local effect of the bradisism, but also global changes in sea level variation) (Simeone & Masucci, 2009).

The complexity of the area is also of great interest since it is the result of anthropic modifications of the tuff substratum, volcanic-tectonic movement and marine erosion. At present further investigation are being carried out in the area to acquire new elements that could lead to a deeper understanding of the Posillipo coastline archaeology, history, environment and geo-archaeology .

These studies and this research were and still are the basis for the development of a protection strategy for the area, as before developing a plan detailed information on the MPA seabed was, of course, necessary. For this reason, it is important to remember that not only an archaeological analysis, but also environmental investigations have been carried out on the area to study the sea life of the MPA seabed and to learn whether the institution of the Underwater Park is having a positive impact on the environment.

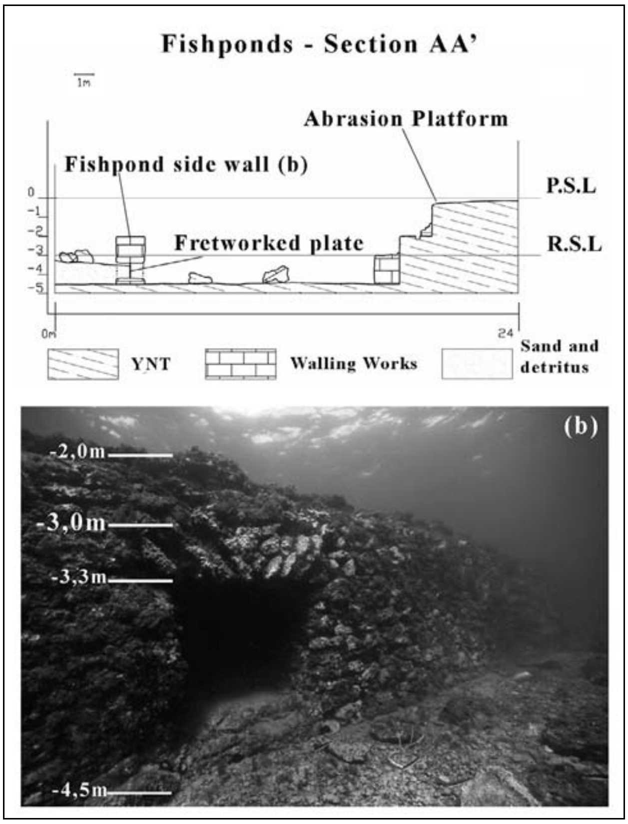

Figure 3 – Sections indicated in Figure 2, with indication of current sea level and estimated Roman sea level. b) side wall of hypogean fishponds, with indication of significant heights. (Photo G. Villani©)

3. THE PRESERVATION AND DEVELOPMENT PLAN

The Marine Protected Area "Gaiola Underwater Park" was formally established in 2002, by an Interdepartmental ministerial order signed by the the Italian Ministry for the Environment, and the governmental authority in charge is the Soprintendenza Speciale per i Beni Archeologici di Napoli e Pompei. In 2005 the Soprintendenza stipulated an agreement with the Centro Studi Interdisciplinari Gaiola Onlus (Interdisciplinary Studies Centre Gaiola: CSI Gaiola), an NGO active on the area since 2004, for the protection and the enhancement of the area. The NGO was created in 2004, as the result of a research project on integrated coastal zone-management of the Posillipo coastline developed in the Department of Enviromental Sciences of the Università degli Studi di Napoli "Parthenope", and composed of a group of young researchers and volunteers with different specialization backgrounds, so that the management and the study of the various features of the area could be guaranteed: archaeologists, cultural heritage managers, biologists, marine biologists, natural scientists and scuba divers. The strong collaboration between the manager authority (Soprintendenza) and the CSI Gaiola made possible in 2005 the development of an operative plan for the protection of the Underwater Park.

Thanks to the data acquired through the research conducted, it has been possible to analyze on the quality and the risk markers that impact the Underwater Park (Table 1). On the basis of this analysis a methodological approach has been developed (Figure 4); the principle is to strictly correlate the research and the dissemination activities.

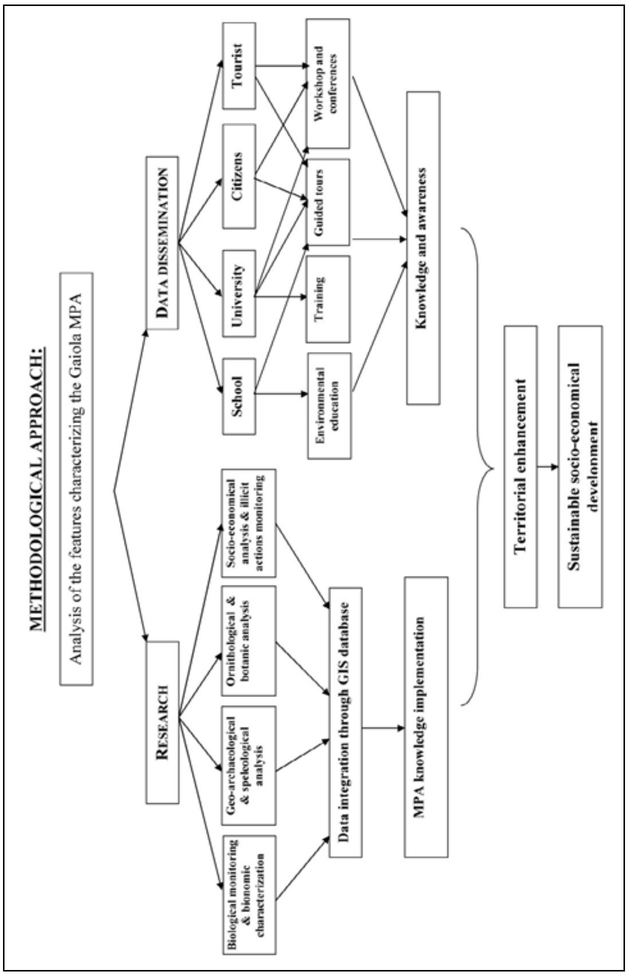

Figure 4 CSI Gaiola Methodological approach to the management of the MPA "Gaiola Underwater Park".

The approach tries to be as interdisciplinary as possible, covering all the fields that need to be analyzed in such a particular environment through different specialization collaboration-groups formed of members of the NGO staff. The aim of the plan is to create sustainable development through two parallel work programmes. On the one hand, there is the scientific research which is needed to acquire knowledge and a deeper understanding of the historical, archaeological and environmental resources of the MPA, and at the same time these resources constitute the focal point on which the protection work programme focuses. On the other hand, an intense data-popularization programme is carried out to increase the local population's awareness of the importance of the area. Learning about the cultural and environmental heritage, and then to appreciate it, may eventually lead to a greater sense of belonging to a place which in turn may lead to a greater sense of responsibility for this heritage and to the sharing of the resources in a sustainable way. This has to involve the participation of all age groups, the new and older generations. The awareness campaigns take place in the MPA and in the Pausilypon Archaeological Park (where the archaeological remains that did not sink are preserved) that in this way become open air workshops where it is possible to observe and feel the close relationship that has always existed between the sea and human beings. Since 2006 several guided itineraries have been created and organized in the Gaiola Underwater Park and the Pausilypon Archaeological Park to allow people to discover the environmental and historical heritage of the sites; the guides are all experts on the area, but the most important thing is that guided tours had never been organized before in this area, and more surprising, many local people did not even known that these area existed. The guided tours are both on land, in the Pausilypon Archaeological Park, and on water in the MPA (by boat, snorkelling and diving); integrated itineraries are also organized.

As far as the data dissemination is concerned however, the most important project developed is the "Sea of Naples" which is an environmental education project for schools and universities. The aim is to guide the new generations towards knowledge and respect of the sea, both from a cultural and naturalistic point of view, through lessons, workshops and games.

Quality markers	Risk markers
- Underwater and partially underwater archaeological structures (I century B.C)	- Territorial and social context
- Great variety in the geo-morphological composition of the seabed	- Extreme anthropic pressure, especially during spring/summer, due to the sea bathing and the yachting
- Highly differentiated sea-life	- Bad management of the coastline, crowding of the sea-bathers inside the Marine Protected Area
- Presence of relevant biocenosis, protected species and characterizing habitat	- Illegal fishing, also by deep trawling that is really invasive (also for archaeological structures)
- High presence of artificial and natural coastal caves	- Difficulties in controlling

Table 1. Gaiola MPA Markers

The objective of this plan is to re-evaluate not only Posillipo but the Neapolitan territory in general, starting with the enhancement and the dissemination of its archaeological, historical and naturalistic heritage. This wealth has not been deployed enough although it can provide the opportunities for developing alternative touristic flows and work for young people interested in cultural development. The aim is to create in the area a centre for the dissemination of the "sustainable development" principles, starting from the new generation. This was done in September 2011 through the organization of a bilateral exchange between Italian and Bulgarian students on the theme of sustainable development in the MPA, thanks to the founding of the European Program "Youth in Action". Cleaning up the area and monitoring illicit actions gradually involving the local population are other important goals of the plan. This would increase the effectiveness and positive results through the creation of a "community spirit" around the park. So many young volunteers and voluntary associations are already involved in the cleaning up and the results of the prevention of illicit actions are disseminated to visitors that come to the MPA by showing pictures, videos and explaining the importance of the results. A fundamental action for the re-development of the area it has been the opening in 2010 of the new Research and Visitor Centre of the MPA (CeRD). The old Centre was set in an old building located at the entrance of the Integral Reserve Area. The building was a tangible sign of the area degradation and it was an obstacle for the real control of the A Zone of the MPA. For this reason the opening of the new centre helped the development of the research and tourist activities and nowadays it is the headquarters for the preservation and enhancement of the area.

Figure 5 A) 2005 – Abandoned building in Zone A of the MPA; B) 2010 – Same building transformed in the Visitor and Research Centre of the Park.

4. CONCLUSION

In the last 10 years important results have been obtained in the Posillipo area, thanks to the collaboration between a government authority and an NGO active in the territory. There is no doubt that the strength of the development plan of the area lies in the interdisciplinary approach which makes it possible to cover all the fields of competence required in such a mixed environment. The results are positive and very promising, especially considering the particular anthropic pressure on the area and the environmental degradation conditions in which it was ten years ago. However, it is also necessary to underline how difficult and complicated it often is to manage the MPA, areas in which historical, archaeological, environmental and social features are mixed together. At the same time, these constituents are an important part of the Mediterranean Cultural and Environmental Heritage.

In the last two decades, thanks to the development of new technologies, the study of underwater remains and the environment has become possible, and it is for this reason that the Marine Protected Areas were gradually instituted all over the Mediterranean, and local institutions started to worry about how this common heritage could best be preserved. The problems to solve are many and varied, also from a legislative point of view. Proof of how interest in this new kind of venture has spread is the 2001 UNESCO Convention for the protection and the preservation of the Underwater Archaeological Heritage (Maniscalco, 2004). The 2001 Convention aimed to fix common rules to make up for the lack of laws regarding the preservation of the underwater heritage in many countries, and it is part of a bigger project named “Environment and Development in Coastal Regions and in Small Islands” which aims to recognize the preservation of the local maritime cultures and environments as an instrument of development. It is also important that citizens, the local population and visitors, become involved and make underwater archaeological sites their own in a sustainable way, especially to support their preservation (Pieroni & Romita, 2003). This aspect is especially important in countries like Italy or Egypt where the archaeological heritage is particularly rich and, consequently, attention is usually focused only on the biggest and most prominent sites (in Southern Italy see the example of Pompei) leaving the smaller realities such as Marine Protected Areas without adequate institutional intervention. In fact, the first problem MPA faces is that the heritage is not immediately visible to most people, and so, of course, it is difficult to ascribe importance to it or to value it. Also, many people are not at ease in water and feel that what lies submerged has nothing to do with them, does not belong to them, but according to the 2001 Convention the preservation of underwater remains entails encouraging conservation of the remains in their original context; the remains have to be left underwater and a way must be found to allow people to “visit” and learn to appreciate them. As Rule 1 of the Convention states: *The protection of the underwater archaeological heritage throughout* in situ *preservation shall be authorized in a manner consistent with the protection of that heritage, and subjected to that requirement may be authorized for the purpose of making a significant contribution to protection or knowledge or enhancement of underwater cultural heritage*.

Because of the new interest in these particular sites ambitious projects have been undertaken such as the plan to build the Archaeological Underwater Museum in Alexandria literally underwater. In 2008 UNESCO decided to nominate a commission to evaluate the real possibility of realizing such a project. The work for the construction of the Museum was supposed to start in 2010, but so far nothing has been done. As the UNESCO commission underlined, the problem is that the project was too ambitious, also considering the fact that before the idea of building an underwater museum presented itself, nothing had actually been done to preserve the Egyptian underwater heritage all over the country (Morcos *et al.*, 2003). The example of Alexandria demonstrates that in MPA management there is still a lot of basic and elementary work to do in many Mediterranean Countries, Italy included, even though some projects, like the VENUS one financed by the European Commission and carried out by different European countries are going in the right direction to study and preserve the underwater heritage in a non-invasive and sustainable way (Chapman *et al.*, 2006).

The results presented in this paper are not the end of a work, but just the starting point for further research, aimed at analyzing the Mediterranean context, is now developing in order to create a model to analyze the new possibilities and way to manage the underwater heritage. The new challenge is now to better understand the original function of some underwater remains, and at the same time to develop a good system to preserve the Gaiola underwater remains, but at the same time let them be accessible to visitors. The help of new technologies will be fundamental in these new projects.

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